90-04495/

DEPARTMENT OF
ENERGY, MINES AND RESOURCES
MINES BRANCH
OTTAWA

Mines Branch Program
on Environmental Improvement

SECOND MINES BRANCH SEMINAR ON ENVIRONMENTAL IMPROVEMENT

by

THE STAFF

Report ADM 71-1

January, 1971

CONTENTS

	Page
1. Agenda	1
2. Introduction	2
3. International and National Pollution Research Collaboration	2
4. Mines Branch Contributions to Environmental Improvement	3
4.1 - Mining Research	4
4.2 - Diesel Testing Facility	8
4.3 - Mineral Processing and Waste Recirculation	10
4.4 - Extraction Metallurgy	12
4.5 - Mineral Sciences	22
4.6 - Physical Metallurgy	24
4.7 - Metals Reduction and Energy	30
4.8 - Fuels Research	33
4.9 - Combustion Research	41
Appendix - Mine Wastewater Treatment (Inland Waters)	47

- - - - -

1. AGENDA FOR SECOND SEMINAR ON MINES BRANCH PROGRAM ON ENVIRONMENTAL IMPROVEMENT

Mineral Sciences Conference Room
555 Booth Street,
Tuesday, November 17, 1970

9:15	Introduction (E. R. Mitchell, Chairman)
9:20	Direction of Environment Program (Dr. J. Convey)
9:30	International Developments in Environmental Management (E. R. Mitchell, Dr. J. Convey)
9:50	National Developments in Environmental Management (E. R. Mitchell)

Contributions to Mines Branch Environmental Program During 1970

10:00-10:20	Mining Research (T. S. Cochrane)
10:20-10:25	Diesel Testing facility (D. Dainty)
10:25-10:35	Mineral processing and waste recirculation (H. Woodrooffe, R. P. Bailey)
10:35-11:00	Extraction Metallurgy (W. A. Gow, Dr. T. R. Ingraham)
11:00-11:10	Mineral Sciences (Dr. A. H. Webster)
11:10-11:20	Physical Metallurgy (Dr. L. V. Whiting, R. K. Buhr)
11:20-11:30	Metals reduction and energy (T. A. Lloyd, G. N. Banks)
11:30-11:50	Fuels research (R. G. Draper, H. Sawatsky, T. E. Tibbetts, B. I. Parsons, W. H. Merrill, W. A. O. Herrmann)
11:50-12:10	Combustion research (G. K. Lee, F. D. Friedrich)
12:10- 1:15	Luncheon Break
1:15- 1:30	Water research, Inland Waters (J. W. Schmidt)
1:30- 3:00	Discussion

2. INTRODUCTION

The first seminar of this series was devoted to establishing an inventory of the principal air pollutants (and water pollutants where the two are inseparable) which are emitted from fuel combustion, mining and mineral processing. Once established, it is intended to expand this inventory and to keep it up-to-date.

The second seminar, described herein, was planned to summarize contributions made by the Mines Branch toward abatement of pollution from the previously mentioned sources. In evaluating the impact of these contributions, an attempt should be made to rationalize the pollution problem objectively by taking into account appropriate checks and balances. One of these is the need of people for technology, without which the present population could not be supported. Pollution, therefore, could be considered coincidental to the support of people because the basic ingredient of technology is heat and this, during our time, will continue to be derived from the burning of conventional fuels; a procedure that produces pollution according to unalterable natural laws.

The Mines Branch, through research, has an active interest in both the economic exploitation of our natural resources (which includes conservation) and the preservation of the environment. In this way we attempt to serve the needs of both government and people.

3. INTERNATIONAL AND NATIONAL POLLUTION RESEARCH COLLABORATION

One of the requirements of the Federal government, not often publicized but important nonetheless, is to contribute to international and national bodies concerned with environmental affairs.

As the world continues to lose ground in the battle against pollution, many international bodies, which the Canadian Government helps to support, have become active in implementing both technical and administrative abatement measures ranging from air management research to global air monitoring. These could augur the beginning of environmental management on a global scale.

Canadian interest in the global atmosphere is obvious when it is considered that our country relies on the world's ventilation system for air supply during the long winter months when oxygen-producing plants are dormant. Indeed, both polar regions are in a precarious position because of the limited capacity of a frigid atmosphere to assimilate pollution compared with either a temperate or tropical atmosphere.

The Mines Branch Plume Dispersion Research Project, using aerial probing techniques, was undertaken to obtain information about the pollution assimilative capacity of our air sheds. The methodology was applied during the past year in the Toronto and Sudbury areas as Mr. G. K. Lee will explain later in these proceedings.

The same methodology, together with personal assistance, has been donated to an OECD (Organization for Economic Co-operation & Development) working party on mass transport of air pollution which is charged with explaining the acid rain phenomenon in Central Europe.

A significant contribution was also made to an OECD Joint Group on Air Pollution from Fuel Combustion. This group is attempting to foresee the pollution burden of the air environment with expanding population and technology.

On a national scale and on behalf of both the Mines Branch and the Department of Energy, Mines and Resources, contributions were made during the year to

(1) the Federal Interdepartmental Committee on Pollution,
(2) the CSA Committee on Air Pollution Control,
(3) the EMR-MOT Interdepartmental Planning Committee on Plume Dispersion Research,
(4) CCRM (Canadian Council of Resource Ministers) Air Pollution Workshop,
(5) Air Pollution Sub-committee of the NRC Associate Committee on Environmental Criteria,
(6) International Flame Research Foundation,
(7) ASME-Fuels Division,
(8) North American Fuel Technology Conference,
(9) Mayor Drapeau's Conference on Air Pollution and Noise,
(10) Air Pollution Sub-committee of the Resource Satellite Program,
(11) a Flame Research Seminar held at CCRL.

4. MINES BRANCH CONTRIBUTIONS TO ENVIRONMENTAL IMPROVEMENT

There are two basic approaches to environmental improvement. One is to prepare and enforce laws and regulations that primarily control the behaviour and attitudes of people; the second is to deal with the environment on a scientific and technical basis to ensure that pollution is kept to a minimum at the source. It is this second approach that the Mines Branch has taken historically and has chosen to emphasize in recent years because of the proliferation of sources through industrial expansion. The expertise that has developed through this activity has made possible the following contributions to environmental improvement in a number of fields during 1970.

4.1 MINING RESEARCH

Improved quality of mine air through research is the prime objective of the Environmental Control Studies.

During 1970, a 7 man-team (3 part time) advanced four projects, established a radiation laboratory, and set up an X-ray bench, at the cost of approximately $90,000 (505 man-days, professional). This progress was detailed in six reports:

4.1.1 Comparative Dust Measurements (G. Knight)

The objective of this work is to develop a dust measuring technique suitable for routine use in Canadian mines. The immediate objective is to determine from the assessment of available instruments and sampling procedures those which are most applicable. During 1970 this study was advanced by:

(1) Analyzing and reporting of performance tests conducted on available dust sampling instruments under controlled laboratory conditions.
(2) Field testing of those instruments most adaptable to Canadian uranium mining conditions as determined by experience and laboratory tests.
(3) Developing of compositional sampling and analytical techniques suitable for field laboratories to allow a more meaningful classification of the dust environment in a mine.

The main laboratory experiments involving the comparison of dust sampling instruments and evaluation techniques under controlled conditions were completed. The results of these studies now contained in 16 internal reports are being compiled and prepared for presentation in the Mines Branch Report format. A draft of the final report is under revision.

Further studies are being conducted on the selective properties of the horizontal elutriator and the cyclone. Initial studies suggest that the material used in construction of the cyclone can cause extreme variability over a range of size distributions. The variability appears to be related to the electrostatic charging of the dust particles. If this can be substantiated, perhaps a conducting material such as metal or certain plastics should be used instead of nylon for cyclones.

The comparison of dust sampling instruments in a uranium mine was initiated during 1970. This is a cooperative study with McIntyre Research Foundation, MAPAO and Mines Branch all making contributions. The contributions of the Mining Research Centre are basically calibration of instruments

and analysis of field data. Two technologists employed by the McIntyre Research Foundation are located at the Elliot Lake Laboratory under MRC guidance. This work was initiated in February 1970 and will continue into 1971.

The Mining Research Centre is also involved in a cooperative study with Department of National Health and Welfare, Department of Labour, and DEVCO. The objective is the setting of dust standards and survey procedures for DEVCO operations.

The initial field survey has been completed and the results are being analyzed. An internal report is being prepared.

The X-ray diffraction equipment is now being calibrated. Samples from the field study are being used to determine the background levels and interferences to be expected.

4.1.2 Dust from Canadian Rocks (G. Knight)

The objective of this project is to study the relationship between the physical and mineralogical properties of rock substances and the concentration, composition and size distribution of the airborne dust produced during the mining of these rock substances. Initially the work consists of:

(1) Conducting the laboratory studies into rock-airborne dust relationships. Rocks of known properties are being subjected to a breakage process and the dust produced is sampled and analyzed.

(2) Analyzing dust samples from the field using X-ray analysis techniques. Airborne samples taken specifically for the Cooperative Compositive Dust Measurement project are being used as feed-in to the X-ray diffraction unit. Samples supplied by outside agencies are also being analyzed using X-ray techniques.

The purpose of the initial phase of the work is to develop the field instrumentation equipment and procedures necessary to make a thorough examination of mining systems from a standpoint of classifying dust environments.

The study conducted by the Mineral Sciences Division at the request of the Mining Research Centre into the use of quantitative X-ray analysis as a means of estimating very small amounts of quartz and pyrite in dust samples was completed. The results of this study indicate that if X-ray diffraction is to be directly applicable to as-received airborne dust

samples, the quality of the samples must be improved. The problems arise from uneven distribution of dust on the filter medium and damage to the samples in transport. This study will be re-initiated when the X-ray equipment at the Elliot Lake Laboratory has been calibrated.

The X-ray compositional analysis techniques required for this project are being developed. Calibration of the X-ray equipment using pyrite and silica standards and determination of background levels have passed the first stage. It is hoped that the X-ray equipment will be completely operational by early 1971.

The preliminary laboratory study to determine the rock-airborne dust relationships resulting from the action of a controlled breakage process (impact) on a rock of known properties (uranium ore) has been completed. The characteristics of the cloud produced in the laboratory have been compared with those of a cloud created by the action of a mining process on similar ore. The results of this work are the subject of an internal report now being drafted.

4.1.3 Clean-up of Mine Air by Underground Filtration (R. Washington)

The objective is to study the relationship between airborne dust and radon daughters and to determine the feasibility of reducing radioactivity by filtering dust from mine air. Various filter media -- industrial, commercial, and make-up are being tested.

The tests on commercial filters are now nearly completed. About two dozen different filters and filter media have been tested, both singly and in various combinations. The results indicated that it is technically feasible to filter and recirculate part of the exhaust air, but the economic advantages must be evaluated for each case individually. An appreciable saving can be realized where ventilation costs are an appreciable fraction of the total operation cost and the initial capital costs and replacement costs of the filters and other equipment required are low enough. This is usually the case only for large operations; the saving for small operations would probably be insignificant.

One or two interesting and significant results have been obtained as "by-products" of the main investigation. For example, it appears that there is positive correlation between the filtration efficiencies for respirable dust and for radon daughters, which implies that the radon daughters tend to be associated with the respirable size particles. Also, the results for blank runs indicate that much of the "super-respirable" (above 5 micron size) dust can be removed simply by providing a large settling chamber in which the air velocity is low.

A paper summarizing the results up to April was presented in May at the Detroit meeting of the A. I. H. A. An additional paper giving the most recent results, and a final evaluation of the data for all the filters, is now being prepared.

4. 1. 4 Calibration of Laboratory and Field Equipment (R. Washington)

The objective is to prepare suitable standards and to calibrate laboratory and field equipment.

A number of calibration tests have been run on the laboratory pulse height analysis (P. H. A.) equipment. The successful tests have indicated that the instrument operation is satisfactory, but the work has been delayed by a series of minor (and one or two major) faults in system components, and by delays in delivery of some items.

A preliminary observation of the background gamma radiation showed that the low-energy background radiation (probably from the Nordic tailings) would require a rather massive shield around the detector to permit the observation of low levels of radioactivity in experimental samples. After several months delay, a supply of concrete blocks was obtained and a temporary shield was built to obtain a better estimate of the amount of shielding required. These tests are not yet complete.

Calibration of the alpha-measuring part of the P. H. A. system cannot proceed further until a suitable current-monitoring device is obtained, in order to avoid overloads (and consequent irreparable damage to the detector) during start-up. As soon as the system is operational, preparation of standard alpha sources for calibration will be started.

At present the gamma detection system is inoperative due to failure of the high voltage supply unit, and a consequent overload to the photo multiplier tube which resulted in damage to this unit also. Both units have been returned to the supplier for repairs.

4. 1. 5 Bibliography - 1970

Knight, G., "Size Selective Sampling", for presentation at One-Day Seminar on Dust Sampling Techniques sponsored by Ontario Department of Health, Toronto, MR 70/10-ID (February 23, 1970).

Kruzick, F. and Washington, R. A., "Mechanical Filtration of Aerosols in Trackless Uranium Mines", MR 70/58-LD.

Washington, R. A. and Regan, R., "Elliot Lake Laboratory Facilities for Study of Radiological Pollution of Air and Water", MR 70/59-ID.

Machacek, H., "Quantitative X-ray Determination of Quartz and Pyrite in Dusts", Technical Bulletin TB 123 (January 1970).

Diegel, J.C., "Testing the Efficiency of Commercially Available Filters for Mine Air Filtration", prepared for the Department of Co-ordination and Placement, The University of Waterloo, Waterloo, Ontario, MR 70/82-ID.

Brooks, J.D., "Set-up and Operational Testing of Pulse Height Analyzer System for Gamma Detection and Counting", MR 70/94-ID.

4.2 DIESEL TESTING FACILITY

4.2.1 Background and Scope of Laboratory Activity

Headlines in the newspapers like "Some Die Years Younger - .....Because government cannot keep Clean Air promises" (Ottawa Citizen, Sept. 1, 1970), have served to make the public-at-large keenly aware of the serious effects that internal combustion engine exhaust can have when excessive exhaust toxicity levels result in environmental concentrations beyond safe thresholds.

This exhaust toxicity problem has long been taken seriously in internal combustion engine applications in confined areas such as mine haulage ways and ore faces, where a proper ventilation rate for each machine is necessary to maintain the health of men working in the restricted environment.

Because the use of diesel-driven machinery has been relatively widespread (it is estimated that there are over 1000 such machines underground in Canada now) and the demand for such vehicles is being apparently maintained, the Department is proceeding with the establishment of the Canadian Explosive Atmospheres Laboratory Diesel Testing Facility to make unnecessary the development of such facilities by the provincial authorities. This facility will make it possible to determine exhaust toxicity and to prescribe safe ventilating rates for any confined area. Also, certification as to the diesel vehicle's flameproofness for use in coal mines and gassy non-coal mines will be involved. Presently, the Alberta Government, through the actions of its Mining Inspectorate, is asking for certification by this Department of diesel vehicles for use in the Alberta mines supplying a segment of the Canadian coal production earmarked for Japan. To date, one coal handling diesel vehicle has been certified and a personnel carrier is in process. Further the Government of British Columbia, again through its Mining Inspectorate, has made it known that it favours the establishment of such a service, adding that it is not satisfactory to rely on government lease of private facilities to do the job. Presumably, expense discourages the establishment of such facilities by provincial authorities themselves.

A similar need has been felt in the past by the inspectorate in Nova Scotia. These three provinces represent areas comprising the greater part of Canada's potential of marketable coal for steel and power production purposes. Their activity, need, and interest point out the timeliness of establishing a federal certification service.

In addition, the same newspaper article mentioned above stated that National Health and Welfare would purchase an $80,000 portable chassis dynamometer. This equipment will be used to cope with light automotive work such as border crossing checks as explained in a telephone conversation of October 29, 1970 with Dr. Winthrop, Chief of the Air Pollution Control Division. He stated however, that this equipment was not capable of dealing with larger vehicles and that an installation such as the CEAL dynamometer facility for which they haven't planned, would be necessary. So, circumstances mutually permitting, the Fuels Research Centre will be making a technical contribution to the work of coping with air pollution by all road vehicles other than automobiles. This activity will complement the industrial pollution work of the Combustion Section.

Further, the laboratory equipment will be suitable for determining the effectiveness of any novel break-through in exhaust emission treatment systems, such as the possible development of an improved oxidation catalyst by the Centre's Catalysis Section.

4.2.2 Present Status

Already delivered to the laboratory is a Dynamatic 400 BHP, A.C. Eddy Current Absorption Dynamometer which incorporates a motoring capability of 150 HP for friction studies and special explosion testing requirements. The speed limitations are 5000 rpm when absorbing and 3550 rpm when driving.

The control system for the dynamometer will be incorporated into a control console which is being produced by Honeywell for delivery in March 1971 and which acts as a control centre for all the other laboratory functions as well.

At the same time, a gas emission analysis system is being built by Beckman in Toronto for delivery also by March 1971 which will permit the analysis of O_2 (0-25%), CO_2 (0-15%), CO (0-7.5%), NO (0-4000 ppm) and CH_4 (0-10%). A process chromatograph, already purchased for the Fuels Research Centre, will be applied to the analysis of the unburned hydrocarbons in the exhaust.

The Department of Public Works first issued working drawings for building modifications to CEAL for approval in October 1970, during

which month approval was given and revisions suggested. J.L. Richards, consultants, now are preparing the revised drawings of the installation.

The revised structural, electrical and mechanical drawings will be submitted to CEAL for approval on November 16, 1970; call for tenders is scheduled for November 23, 1970; contract will be awarded January 10, 1971; construction is to start January 20, 1971 and final completion is expected to be September 30, 1971.

4.3 MINERAL PROCESSING AND WASTE RECIRCULATION

Considerable effort has been directed to this program within MPD since the first seminar, and our work in five broad areas relating to the program is reported as follows.

4.3.1 Effect of Processing System on Character of Wastes

In our studies in the wet concentration of minerals, we recognize an interface between processing and effluent or waste disposal. It, therefore, is of concern to study the processing system in relation to the environmental problem and its alleviation. MPD is quite conscious that process metallurgy may be modified to effect the character of wastes, particularly effluents. One aspect of this area is a study of the degradation of flotation reagents.

Once a reagent has performed its function in the separation process, there is no longer any reason to preserve its integrity and thereby affect the effluent or the particulates in it. There are two approaches, chemical and biological. A number of new types of reagents that show promise in the separation of non-metallic minerals are proving to be biodegradable to some degree. While the mechanism of degradation has not been fully explored, it is sufficiently attractive to open an interesting area of study. During the past year, the Mineral Processing Division's research has resulted in two new separation systems, one for celestite from other carbonates, and the second for the recovery of a low-iron spodumene by reverse flotation. In both cases the reagent scheme incorporates compounds that degrade within one to two days. These systems are protected by patent application. Pioneering of this kind is well suited to non-metallic flotation since normal reagents are more costly than those incorporated in the sulphide systems. We hope to develop a cooperative project in furthering the degradation study.

4.3.2 Recirculation of Process Water in Concentrators

In normal gravity processes, recirculation of process water is straight-forward. However, in flotation, the effect on metallurgy of a specific operation has the greatest significance.

While the principles of recirculation are well known and are reported in the literature, their application to an individual concentrating plant presents a specific research case, since reagent balance, the character of the ore, and of local water, have an essential part to play in seeking a solution. During the past year, a literature survey has been prepared and will shortly be released as Internal Report MPI 70-37. We have concluded that in a complex flotation operation, if each phase is considered as a unit with its own recirculation system rather than one overall recirculation system, the problem is simplified. This may, however, require a slightly higher capital investment to achieve.

4.3.3 Circulation of Waste in a Processing System

This area is not significant to the conventional concentration process except where a system has evolved that is complex and contains several different types of processing. No example comes to mind at this time.

4.3.4 Conversion of Solid Mineral Wastes to Useful Products

The processing of solid mineral wastes has been a fruitful subject for research and several projects have been successfully completed in MPD.

An iron oxide precipitator dust from steel operations, unsuitable for reprocessing, was studied. Several different approaches were investigated for using this material. Of these, the most successful was a combination with high-lime clays and shales of southwestern Ontario to produce a high quality building brick and a high density salt-resistant curbing material for special applications. High-lime clays and shales of the region are not by themselves suitable for products of this kind. A report on this research is in preparation.

In a second project, residue from fertilizer plants was studied. The research has been successful in developing a process whereby these residues can be converted into gypsum products including plasterboard. Currently, a western gypsum product plant is considering the possibility of applying this process commercially. A research report is in preparation.

In another project, a process was developed for recovering chromite from used foundry sand. This process has now been placed in

operation at a Canadian steel foundry with a considerable financial saving in foundry costs. The process is described in IR 69-13.

In another case, stainless steel machine turnings were upgraded to a quality suitable for melting scrap. This process is now in use by Atlas Steel and at two or three locations in the United States.

Recently we developed a means for crushing battery cases and recovering the contained lead by gravity.

Finally, we have been experimenting with the possibility of converting fly ash from thermal power stations into lightweight aggregate and pozzolan.

4.3.5 Land Pollution

The disposal of tailings materials is a case of pollution of this type. We are currently studying dry processing techniques for potash with the object of leaving much of the salt tailings underground.

4.4 EXTRACTION METALLURGY

4.4.1 Current Project Titles

- (1) Percolation Leaching of Uranium Ore (V.M. McNamara and H.H. McCreedy)

This project is a study of percolation leaching of uranium ore with bacterially-active solutions in the underground workings of a mine. This method reduces the amount of acid required for leaching, reduces the total volume of solution that is required to leach the whole ore body and keeps the leaching agent confined to the underground, thereby reducing the possible contamination of the water courses. Methods of recovering the dissolved metals are also being examined.

- (2) Pressure Leaching of Cu-Ni-Fe Flotation Concentrates with the Formation of Elemental Sulphur (A. Vezina)

This project is designed to determine the feasibility of pressure leaching a relatively low-grade bulk flotation concentrate. The method eliminates the air pollution associated with smelting of concentrates and converts a substantial amount of the sulphide sulphur to elemental sulphur which can be collected.

- (3) Flotation of Sulphur (W. R. Honeywell)

Experimental work is being done to determine the feasibility of recovering elemental sulphur from waste residues remaining after the pressure leaching of copper-nickel-iron sulphide concentrates.

- (4) Recovery of Base Metal Values from Waste Solutions by Ion Exchange (A. J. Gilmore)

This project is designed to test the economic and technical feasibility of removing and recovering trace amounts of base metals from waste solutions from metallurgical and mining plants.

- (5) Rare-Earth Extraction from Acid Sulphate Solutions (G. M. Ritcey and B. H. Lucas)

This project is directed towards the recovery of rare-earths from uranium-barren solutions. At present the rare earths are precipitated as a result of normal neutralization procedures but, not being recovered, add to the volume of solid waste to be disposed of.

- (6) Recovery of Mercury from Waste Solutions (H. H. McCreedy and V. M. McNamara)

Leaching methods are being examined to extract mercury from a waste sludge which occurs in the production of chlorine with mercury-amalgam electrolytic cells. Methods of recovery of this leached mercury and that dissolved by the chlorine process, are being studied.

- (7) Chlorination of Metallic Sulphides (T. R. Ingraham)

In order to eliminate the formation of sulphur dioxide when sulphide minerals are roasted in an oxidizing atmosphere, a scheme is being investigated that involves the leaching of the crushed sulphide mineral with dilute hydrochloric acid. This process leads to the formation of metallic chlorides and hydrogen sulphide gas. The hydrogen sulphide can be converted to elemental sulphur by the Klauss Process. The metallic chlorides can be recovered from solution and then roasted in an oxidizing atmosphere which allows metallic oxides to be recovered and hydrochloric acid to be regenerated.

- (8) Use of Metallic Oxides as Absorbents for Sulphur Oxides in Gas Streams (T. R. Ingraham)

Investigations have shown that one of the most likely candidates for the absorption of sulphur dioxide from dilute gases is magnesium oxide. MgO alone is not suitable but requires the presence of catalysts to aid in

forming $MgSO_4$ from the MgO and SO_2. An interesting feature of this material is that the MgO is regenerated, no sulphides are formed, and the product of regeneration is elemental sulphur. However, the quantitative aspects of regenerating elemental sulphur have not yet been determined.

- (9) Chemical Reactions Between Limestone and Sulphur Oxides in Gas Streams (T. R. Ingraham)

The reaction between limestone and sulphur dioxide has been widely investigated and it has been studied on a pilot plant scale in the United States and Canada by injecting limestone into the boiler tubes at thermal heating plants. Only about 35% of the SO_2 has been recovered. The reason relates to a lack of reactivity of the limestone. The solution of this problem seems to lie in discovering a means of increasing the reactivity of the limestone and of discovering the optimum conditions first for the removal of carbon dioxide from it and then for the recombination of sulphur dioxide with the residual calcium oxide.

- (10) Evaluation of Ontario Limestones as Absorbents for Sulphur Oxides in Gas Streams (T. R. Ingraham)

A simple technique involving continuous gas analysis was developed to assess the relative reactivities of a series of commercial samples of limestone and dolomite submitted by Ontario Hydro's Research Division in Toronto. The technique permits assessing the sulphur dioxide absorption of the calcined stones at various temperatures, particle sizes, gas compositions, and after various degrees of conversion to calcium sulphate. The experiments simulate the conditions of limestone injection into steam boilers. The most reactive samples were those limestones that have a high CaO content and a high degree of microcrystallinity.

- (11) Equilibria in the Nitrogen-Oxygen System at Steam Boiler Temperatures (T. R. Ingraham)

Published data have been used in a computer program to study the changes in the parts per million of nitrogen oxides that are in equilibrium with the elements at the temperatures within a steam boiler. The effect of reducing the excess of air required for combustion is illustrated and it is suggested that the benefit/cost ratio is favourable for research to develop a catalyst for the low-temperature equilibration of NO with its elements.

- (12) Problems in the Analysis of Caustic-Cell Brine Sludges for Mercury (R. J. Guest)

An investigation was carried out to establish the cause of poor metallurgical balances on products from processes to remove mercury from caustic cell sludges. The effect of variations in a large number of the steps

of the analytical method were studied, using standard additions and it was established that mercury was being lost during the drying of the samples prior to analysis.

- (13) Analytical Methods for Flotation Reagents (E. Rolia)

Analytical methods are being developed for flotation reagents, particularly sulphhydryl collectors, in the low ppm range. Methods have been developed for alkylxanthates, dixanthogens, dialkythionocarbamates and dialkyl dithiophosphates. The studies are primarily directed towards improving metallurgical control by regulating reagent addition. From the pollution standpoint, the project has two applications, 1) limitation of reagent addition to the amount actually needed, 2) monitoring effluents (solids and liquids) for these constituents.

- (14) Factors Influencing Arsine Evolution During Gold Precipitation from Cyanide Solution (J. C. Ingles)

The effect of variations in concentration of the constituents normally present in cyanide solutions on the proportion of arsenite reduced to arsine and elemental arsenic (pH, cyanide, carbonate, lime, gold, etc.) has been studied. Methods for limiting arsine evolution by changing the oxidation state of the arsenic, by the addition of reagents to modify reduction potentials and by the use of colloids and surface-active reagents to modify the double-layer at the zinc surface are being investigated.

- (15) Proceedings of the Canadian Mineral Processors (C. S. Stevens)

The Canadian Mineral Processors which is an organization of mill superintendents and metallurgists of gold and non-ferrous base metal mines of Canada has been aware for some time of the problems of environmental pollution arising from mining and milling operations.

To assist their members in meeting these problems the following papers were presented at their annual meeting in 1970:

1) The Hydraulic Construction of Mine Tailings Dams - Mr. Bert Hoare and Mr. H. M. Hill, University of Waterloo.

2) Mine Tailings Dam Construction in Ontario - Mr. Kim Shikaze, O. W. R. C.

3) Water Reuse at Inco Sudbury Mills - Mr. R. N. Browne and Mr. H. R. Butler.

4) Background Information on N. B. Reclamation Project (Minto Coal Field) - Mr. Barry B. Meadows.

At the Annual Meeting in 1969 the following papers were given:

1) Growth of Vegetative Cover on Tailings Disposal Area

(a) The Use of Vegetative Cover to Stabilize Mine Tailings Areas at Copper Cliff - Mr. C. A. Young, INCO.

(b) Erosion Control of Hollinger Mine Tailings Site - Mr. I. M. Gordon.

2) Pollution Problems Associated with Base Metal Mines - Dr. A. E. P. Watson, Inland Waters Branch.

3) Abatement of Pollution from Mine Waste Waters - Mr. J. W. Schmidt and Mr. K. Conn, Inland Waters Branch.

4) Tailings Disposal of No. 12 & No. 6 Concentrators at Brunswick Mining and Smelting Corp. Ltd. - Mr. G. W. Neuman.

4.4.2 The Abatement of Sulphur Dioxide and Nitrogen Oxide Air Pollutants (T. R. Ingraham for the Research Section)

Sulphur dioxide and nitric oxide are two of the most common and hazardous of the atmospheric pollutants that occur in both urban and rural atmospheres in Canada. Sulphur dioxide occurs in gas effluents wherever sulphurous fuels (coal or oil) or sulphide minerals are processed by combustion. Nitric oxide is always produced whenever the nitrogen and oxygen in air are exposed to the very high temperatures that occur in arcs, flames, internal combustion engines and in many pyrometallurgical processes. Sulphur dioxide is harmful because it produces micron-size sulphate dusts that are ingested into the body. Nitrogen oxide is physiologically active in the same manner as carbon monoxide.

Although sulphur dioxide pollution could be eliminated if it were possible to desulphurize coal and oil to the same degree of effectiveness as natural gas, the nitrogen dioxide problem is somewhat different because it is not likely that nitrogen would be entirely eliminated from the company of oxygen in the process of combustion.

On the assumption that it may be some time before effective desulphurization of fuels can be attained, and nitrogen is eliminated from the company of oxygen at high temperatures, the Research Section has been working with Ontario Hydro in studies related to sulphur dioxide and nitric

oxide removal from stack gases. Because the compositions of waste power plant effluents are essentially similar to those of metallurgical plants processing sulphide ores, the work also has applications in metallurgy. In additional studies, work is being done to develop alternate means for processing sulphide ores in a manner that does not generate oxides of sulphur (SO_2, SO_3 or sulphates).

During the period covered by this review, a series of limestone samples from Ontario Hydro was subjected to a new test method that we devised to determine their effectiveness in removing sulphur dioxide from stack gases (1). When it was observed that their general effectiveness was marginal, a study was made of the absorption reactions to discover the steps involved (2, 3). The work showed that there were intermediate stages in the absorption process. The final product was always predominantly calcium sulphate. Because of the stability of calcium sulphate, it is likely to be a throw-away product. Aside from the waste involved in discarding calcium sulphate, limestone injection schemes really only trade an air pollution problem for a land-pollution problem. In the search for an absorbent that could be regenerated and would produce a saleable by-product, work was begun on a new process involving magnesium oxide. The oxide is suspended in a finely divided form in a support. It is very reactive and removes SO_2 effectively from dilute and concentrated sulphur-dioxide effluents. The resulting sulphate may be regenerated readily, in situ, at the same temperature, merely by changing the reducing power of atmosphere over the absorbent. The products of regeneration are magnesium oxide of undiminshed activity and either concentrated sulphur dioxide or molten sulphur. The former would be selected if acid making were contemplated; the latter if long term storage or shipment were involved. The minimum cost for this method of sulphur recovery from sulphur dioxide is about $23 ton and is probably somewhat less than methods involving direct reduction with natural gas. This is the estimated base level cost of diminishing pollution by sulphur recovery. It is considerably higher than that required to produce sulphur from hydrogen sulphide. A report is being prepared for publication of the work (4).

Because of the ease with which sulphur may be recovered from hydrogen sulphide, means were sought whereby sulphide ores could be processed directly to produce hydrogen sulphide without the intermediate formation of sulphur dioxide. Because of the very high rate of reaction and the ease with which hydrogen chloride may be regenerated from chloride solutions, a series of literature reviews were made (5, 6, 7) to establish a working position. Subsequent experimental work has confirmed that sulphide dissolution in hydrochloric acid is indeed rapid; a small plant could process a large tonnage of concentrate in a short time. A computer model of the leaching reaction has been made (8). The acid can be almost completely consumed and strong solutions of base metal chlorides may be produced. After appropriate chloride separations, either high grade oxide or powdered metals may be recovered.

The hydrogen sulphide could be treated directly by the Claus reaction or it could be used in a secondary reaction to produce elemental sulphur from waste sulphur dioxide. The process has the advantage of being run alone on a small scale or of being advantageously integrated with a large process in which waste sulphur dioxide is produced.

Our studies on the nitrogen oxide problem are only in the initial stages. One report (9) has been issued to Ontario Hydro in which the number of parts per million of NO and NO_2 have been related to equilibrium conditions at a variety of temperatures and of nitrogen and oxygen concentrations. Data are now being gathered for a computer model of the formation and decomposition of NO and NO_2 during the short residence times and temperature conditions that prevail within the flames and down the tubes of a steam boiler (10).

References

1. "Evaluation for Ontario Hydro of the SO_2 - Fixing Capability of Some Ontario Limestones and Dolomites", by T. R. Ingraham and N. J. Ramey, Mines Branch Investigation Report 70-14, March 4, 1970.

2. "Mechanism of SO_2 Absorption with Limestone", by T. R. Ingraham and P. Marier, Extraction Metallurgy Internal Report 70-10, April 23, 1970.

3. "The Role of Calcium Sulphite in Desulphurizing Gases Containing Sulphur Dioxide", by P. Marier and T. R. Ingraham, Mines Branch Research Report 222, March 1970.

4. "Elemental Sulphur Recovery from Waste Gases Containing SO_2", by P. Marier and T. R. Ingraham, (in preparation).

5. "The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides - Part I: The Generation of H_2S from Base Metal Sulphides", by H. W. Parsons and T. R. Ingraham, Mines Branch Information Circular 242, June 1970.

6. "The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides - Part II: The Recovery of Sulphur from Gases Containing H_2S", by R. F. Pilgrim and T. R. Ingraham, Mines Branch Information Circular 243, June 1970.

7. "The Hydrogen Sulphide Route to Sulphur Recovery from Base Metal Sulphides - Part III: The Recovery of Iron Products from Ferrous Chloride Solutions", by D. A. Reeve and T. R. Ingraham, Mines Branch Information Circular 244, June 1970.

8. "Pyrrhotite Leaching with HCl to Produce H_2S", by H. W. Parsons and T. R. Ingraham, (in preparation).

9. "Equilibria in the N-O System at Steam Boiler Temperatures", by T. R. Ingraham and D. J. MacKinnon, Mines Branch Investigation Report 70-58, October 6, 1970.

10. "The Rates of Formation and Decay of NO_x under the Time and Temperature Conditions Prevailing in a Steam Boiler", by D. J. MacKinnon and T. R. Ingraham, (in preparation).

4.4.3 Relevant Publications Jan. 1-Oct. 1, 1970

EMI 70-8 Recent solvent extraction work at the Extraction Metallurgy Division of Mines Branch, by G. M. Ritcey and B. H. Lucas.

Describes methods for the treatment of mill effluents to recover useful by-products, which otherwise may be regarded as pollutants.

EMA 70-22 Co-extraction of uranium and thorium from sulphuric acid solution and recovery by selective stripping, by G. M. Ritcey and B. H. Lucas.

Describes methods for the treatment of mill effluents to recover useful by-products, which otherwise may be regarded as pollutants.

TB 113 Stage-wise separation of uranium, thorium and rare earths by liquid-liquid extraction, by G. M. Ritcey and B. H. Lucas.

Describes methods for the treatment of mill effluents to recover useful by-products, which otherwise may be regarded as pollutants.

IC 237 Solution purification by ion exchange and solvent extraction, by G. M. Ritcey.

A survey of ion exchange and solvent extraction techniques and equipment for the recovery and separation of metals. These techniques have potential applications in the treatment of mine and mill effluents, and possible applications in the removal of pollutants from gas streams.

IC 252 Ion exchange recovery of copper, zinc, and nickel from acid sulphate and alkaline cyanide waste water, by A. J. Gilmore.

A survey of applications of ion exchange to the removal of metals from dilute process waste streams.

IC 242 The generation of H_2S from base metal sulphides, by H. W. Parsons and T. R. Ingraham.

A review of methods that have been proposed for recovering hydrogen sulphide from base metal sulphides. Pyrrhotite, a common Canadian mineral often associated with nickel, copper, cobalt, lead and zinc, appears amenable to treatment with hydrochloric acid to yield hydrogen sulphide.

IC 243 The recovery of sulphur from gases containing H_2S, by R. F. Pilgrim and T. R. Ingraham.

A review of variants of the Claus reaction for recovering sulphur from hydrogen sulphide.

IC 244 The recovery of iron products from ferrous chloride solutions, by D. A. Reeve and T. R. Ingraham.

A review of methods for recovering hydrogen chloride and iron products from aqueous acidic solutions of ferrous chloride.

R 222 The role of calcium sulphite in desulphurizing gases containing sulphur dioxide, by P. Marier and T. R. Ingraham.

Calcium sulphite is an intermediate in the sulphation of calcium oxide with gases containing sulphur dioxide, and its properties control the behaviour of calcium oxide as an agent for removing sulphur dioxide from gas streams.

IR 70-14 Evaluation for Ontario Hydro of the SO_2-fixing capability of some Ontario limestones and dolomites, by T. R. Ingraham and N. J. Ramey.

Describes a method for evaluating the effectiveness of various Ontario limestones and dolomites as absorbents for sulphur dioxide from gaseous effluents.

IR 70-58 Equilibria in the N-O system at steam boiler temperatures, by T. R. Ingraham and D. J. MacKinnon.

Published data have been used in a computer program to study the changes in the parts per million of nitrogen oxides that are in equilibrium with the elements at the temperatures within a steam boiler. The effect of reducing the excess of air required for combustion is illustrated and it is suggested that the benefit/cost ratio is favourable for research to develop a catalyst for the low-temperature equilibration of NO with its elements.

IR 70-31 Analytical methods for collectors used in the flotation mill at the Kidd Creek Concentrator, Ecstall Mining Ltd., Timmins, Ontario, by E. Rolia.

Titration and extraction spectrophotometric methods applicable to alkylxanthates and dialkyl dithiophosphates in typical flotation mill pulps and tailings discharge streams.

EMA 70-17 Analytical methods for sulphhydryl collectors in flotation liquors, by E. Rolia.

A review of the chemistry of sulphhydryl collectors and a summary of analytical methods.

EMA 70-11 Analytical methods for flotation reagents - Part 1: Differential iodimetric titration method for alkylxanthates, by E. Rolia.

Describes a differential iodimetric method for xanthate with specific modifications to permit its determination in the presence of sulphite, cyanide and sulphide by the use of pH and potential-buffering materials, and complexing and precipitating agents. A specific modification, based on a novel separation of xanthate, permits its determination in the presence of thiosulphate.

EMP 70-1 and 70-2 Arsine gas evolution in cyanide leaching; causative factors.

This project has not yet been reported except in the semi-annual reports referred to. The work may be summarized as follows:

"It has been found that arsine evolution can be reduced to very low levels by the addition of a potential-buffering reagent. At low concentrations of this reagent the arsenic is reduced to the elemental form, and precipitates out, while at higher concentrations the arsenic remains in the barren. The reagent has no harmful effect on gold recovery."

4.5 MINERAL SCIENCES

4.5.1 List of Projects

The number of projects being conducted in the Mineral Sciences Division as contributions to the Mines Branch Program on Environmental Improvement is being increased considerably. The following studies either are now underway, or have been approved for commencement in the immediate future.

- (1) A Study of the Influence of Structure and Composition of Pyrrhotite on its Reactivity in the Dissolution Process (L. J. Cabri)

Mineralogical and crystallographic examinations of pyrrhotite samples and leach residues are being made on material from HCl-leaching experiments being conducted in the Research Section of the Extraction Metallurgy Division. The purpose of the project is to determine whether the dissolution behaviour of the pyrrhotite is affected by the type of pyrrhotite being treated. It is hoped that the information obtained may aid in the development of hydrometallurgical processes for the treatment of sulphide ores that would obviate the production and release of sulphur dioxide during smelting. The work is being done in close consultation with Dr. T. R. Ingraham.

- (2) Phase Equilibrium Studies in the (Fe, Co, Ni)-S-Cl Systems (A. H. Webster and R. H. Lake)

In the search for methods of treating sulphide ores to produce H_2S (which can be converted to elemental sulphur) instead of SO_2, the treatment of the sulphides at elevated temperatures with HCl and steam has been considered by the Research Section of the Extraction Metallurgy Division. In order to obtain an understanding of some of the physical-chemical phenomena involved in this process, a knowledge of the phase diagrams of the systems $FeS-FeCl_2$, $NiS-NiCl_2$ and $CoS-CoCl_2$ is required. It is the purpose of this investigation to determine the phase diagrams using differential thermal analysis in conjunction with powder X-ray diffraction.

- (3) An Investigation into Methods for the Reduction of Pollutant-Gas Content of Effluent Gases from Industrial Operations (H. P. Dibbs)

Currently large amounts of SO_2 are discharged by thermal power stations and by smelters. A literature review is being undertaken of existing methods of SO_2 control and an examination will be made of possible new approaches in this area that will use regeneratable absorbents.

- (4) Exchange Capacity of Open Lattice Silicates (G.H. Faye)

Certain naturally-occurring open lattice silicates, such as montmorillonites and zeolites, have a marked ion-exchange capacity. Most of the studies on their exchange properties have dealt with alkali and alkaline earth metals. The objective of this project will be to determine the exchange capacity of relatively abundant natural silicates for base metal cations, Fe, Co, Ni, Cu, Zn, Pb, Hg, under a variety of experimental conditions. If the above materials prove to have an adequate exchange capacity, they may be useful in combating pollution problems associated with mine drainage waters.

- (5) The Effect of Slag Heaps and Tailings on the Pollution of Water (A. Jongejan)

Initially, synthetic slags of various compositions and in different states of crystallization will be prepared, and will be examined by leaching with dilute sulphuric acid in a suitable percolation apparatus. It is proposed to extend the studies to actual slags and tailings from metallurgical operations. Slags from the smelting of sulphide ores still contain small quantities of sulphide that can acidify water and subject the slag to leaching, and hence contribute to the contamination of ground waters. This project should provide information on the extent of this problem under a variety of controlled conditions.

- (6) The Systematic Determination of Minor Elements in Canadian Ores (G. L. Mason and A.H. Gillieson)

Analyses will be made, initially, on samples from as many producing metalliferous mines in Canada as possible, chiefly by emission spectrographic analysis, but augmented by other methods where necessary. After completion of the initial stage, the project might be extended to dormant or depleted mines. Although this project is particularly concerned with the possibility of the economic recovery of elements not now extracted from the ores, the information obtained should be of value in providing data for pollution control and health agencies. Close liaison with the Geochemistry Section of the Geological Survey will be maintained.

4.5.2 Publication for the Period January 1 to October 1, 1970

"Quantitative X-ray Determination of Quartz and Pyrite in Dusts", by H. Machacek, Mines Branch Technical Bulletin TB 123, January 1970.

The quantitative direct X-ray determination of quartz and pyrite in airborne mine dusts was investigated. A new technique developed by Leroux and Powers has been successfully applied and some new details have been found. The method provides reproducible analyses of quartz and pyrite in dust samples.

When the calibration curves of the pure components have been made and certain sources of error are kept within appropriate limits, quartz and pyrite can be determined down to 30 $\mu g/cm^2$ when deposited on appropriate filters. This work was done in cooperation with the Mining Research Centre.

4.6 PHYSICAL METALLURGY

4.6.1 Fume Control in Refining Secondary Aluminum (L. V. Whiting)

Introduction

The use of chlorine gas in the aluminum industry represents an obvious pollution hazard. It is used for (1) cleaning melts of oxides and dross; (2) degassing melts, (3) removing magnesium from secondary scrap melts so that they meet the chemical composition specification. These are accomplished by bubbling chlorine through the melt and gaseous products or pollutants, excess chlorine, HCl and volatile $AlCl_3$, must be collected. The toxicity and corrosive properties of chlorine and HCl are known. However, only a little is known concerning the effects of $AlCl_3$ on humans (1) and nothing of its effects on the environment.

Degassing and Cleaning

At its inception, this work was to examine the uses of chlorine in the aluminum industry. A literature survey has shown that cleaning the melt of inclusions and degassing the aluminum of dissolved hydrogen may be achieved by filtration in a continuous in-line system without the need for fume control. Equipment has been described (2-4) to filter and simultaneously degas molten aluminum by passing it through a bed of refractory granules while an inert gas, frequently argon, is passed up through the bed. Hydrogen content may be reduced from 0.48-0.30 ml to 0.17-0.08 ml/100 g of metal. The use of chlorine was found to clog the filter.

Commercially, hydrogen is removed by treatment with chlorine, hexachloroethane, nitrogen and argon or mixtures of these (particularly chlorine and nitrogen). The use of the first two results in problems of fume control, while nitrogen increases the inclusion content of the metal.

Many consider the mechanism of hydrogen removal by chlorine to be a combination of physical and chemical processes. To reduce hydrogen, initially 0.5-0.3 ml/100 g of aluminum, to a level of 0.2-0.1 ml/100 g aluminum requires 1-15 lb chlorine/ton of metal in a period of 10 min. Although 30% as effective as pure chlorine, a 10% chlorine-90% nitrogen mixture delivered at a lower rate at least 1 ft below the melt surface causes less atmospheric contamination.

Removal of Magnesium

Attention should therefore be directed to the present use of chlorine to remove magnesium, calcium, sodium, nitrides and carbides from secondary aluminum into the slag. B. Lagowski (5) of this Division has found that the reaction of 10% chlorine-90% nitrogen with aluminum melts containing 1/2% Mg removed magnesium initially with 90% efficiency at temperatures above 710°C (1310°F) and 20% below 690°C (1270°F). Another investigator (6) reported that HCl or steam and chlorine were twice as rapid as pure chlorine for reducing the magnesium content to 0.1% Mg.

Thermodynamically, the removal of magnesium from aluminum by chlorine in the form of $MgCl_2$ is favoured below 1500°C (2700°F). Kinetically, $MgCl_2$ formation should be favoured over that of $AlCl_3$ at concentrations above 0.05% Mg provided that the reaction is not diffusion controlled.

Experiments were performed in which 20% chlorine-80% nitrogen was bubbled gently into molten aluminum containing 1/2-1% Mg for an hour at different temperatures. The crucible was covered by a loose-fitting graphite lid. Gases were withdrawn from above the melt by a water aspirator and were treated to remove chlorine, HCl and $AlCl_3$ before the gases reached the aspirator. The rate of magnesium removal was constant with time (at least to 0.1% Mg). These experiments have been continued but results are not available.

The high reactivity of the unused chlorine made its removal from above the melt difficult and the chemical analyses for this element were in error. The removal of $AlCl_3$ from the gas also represents a problem as it is solid below 178°C (352°F) and forms fine particles which pass with the gas through water without being appreciably dissolved. When vaporized it could not be condensed efficiently as it solidified too readily before reaching the cold surface. However, the particles formed in this manner appeared much larger and filtration of the gas should lead to their removal.

Other investigators (7) have found that the removal of $AlCl_3$ by scrubbing towers was only 72% effective or only 87% effective with very fine spray nozzles, whereas other metal chlorides could be removed with more than 99% efficiency. The reaction of $AlCl_3$ with steam above 300°C (600°F) results in the formation of large particles of $Al(OH)_3$ suitable for filtration (8). The application of these methods would make the use of simple analytical techniques difficult to determine more than one of chlorine, HCl or $AlCl_3$.

The obvious difficulty of collecting $AlCl_3$ for chemical analyses has made it appear that the cost necessary for anti-pollution collection devices might be excessive and perhaps a less costly approach would be to decrease or eliminate the formation of volatile $AlCl_3$ in the first place.

The fused salt mixture LiCl-KCl-$MgCl_2$ has a wide range of $AlCl_3$ solubilities at 670-730°C (1240-1350°F) (up to 70 mole %) (9). Experiments have been initiated with this salt mixture to determine its ability to remove magnesium by agitation with an inert gas or by chlorine. Analytical data are not presently available but a problem was encountered when iron from the thermocouple probe dissolved causing the fused salt to adhere as a solid to the walls of the crucible.

References

1. E. Browning. Toxicity of Industrial Metals. Ch. 2, Butterworths, London, 1961.

2. K. J. Brondyke and P. D. Hess. Filtering and Fluxing Processes for Aluminum Alloys. Trans. AIME 230, 1553-1556 (1964).

3. P. D. Hess, K. J. Brondyke and N. Jarrett (Alcoa). U. S. Pat. 3,172,757, Mar. 9, 1965.

4. M. V. Brant, D. C. Bone and E. F. Emley. Fumeless In-line Degassing and Cleaning of Liquid Aluminum. TMS Paper Selection No. A70-51.

5. B. Lagowski. Magnesium Loss During Chlorination of Aluminum Melts. Mod. Cast (AFS Trans.), 56, 205-207 (1969); PMD Internal Report PM-M-69-4.

6. Metalhutte Mark Akt.-Ges. Refining Aluminum. Brit. Pat. No. 820,630, Sept. 23, 1959.

7. P. P. Gertsen, Y. M. Kosykh, N. L. Subocheva, L. I. Ionova and A. G. Romanov. Purification of Waste Gases from Titanium Production in Scrubbers with Water Spraying. Sb. Nauchn. Tr., Permsk. Politeckhn. Inst. No. 18, 107-119 (1965); C. A. 65: 19735g.

8. J. J. Donoso. Removal of Aluminum Chloride from Smoke. Proc. Smoke Prevention Assoc. Am. 1947, 39-42.

9. H. Grothe and C. A. Piel. Fusion of Salts for Aluminum Chloride Electrolysis. Z. Electrochem. 54, 210-5 (1950).

4.6.2 Reduction of Particulate and Gaseous Pollutants from Cupolas (R. K. Buhr)

The recent legislation passed by the Province of Ontario regarding Air Contaminants From Ferrous Foundries, and effective Sept. 1, 1969, has caused concern among many of the foundries affected, especially the smaller operators. Although the legislation allows cupola operators producing less than 10 tons of iron per hour to emit a maximum of 75 lb of particulate per hour, the majority of the operators do not know what the particulate emission from their operation produces. As a result, they either purchase costly dust collecting equipment which may or may not be required, or they cut back on their production per hour to be on the safe side, simply installing an after-burner as required for all cupolas in the legislation.

It is anticipated that legislation will be passed in other provinces which limits the emissions from cupolas. Consequently, research is required to obtain not only the information on the magnitude and nature of cupola emission, but also to carry out investigations on the process itself in an effort to reduce the particulate and gaseous emissions in the operation.

We expect to receive approval to construct an experimental cupola in the 1971-72 fiscal year. To date, our efforts have been concentrated on a search of the literature and we are attempting to get answers to the following three questions:

1. What is the nature and quantity of pollutants from cupolas?
2. What work has been done to reduce pollution from cupolas?
3. What information is available on experimental cupola design?

(1) A translation of a thesis written by Mr. Gerhard Engels of Germany was one of the better references found dealing with the first question. This thesis was a survey of a large number of German cupolas, which, among other things, determined particulate and gaseous emissions. Although these results should not be directly applied to North American practice because of the lower carbon and higher ash content of European foundry coke, the findings are a good indication of the nature and quantity of cupola emissions.

In cold-blast cupolas, Mr. Engels reports top gas dust contents varying between 4 and 40 lb per ton of iron melted. Top gas analysis varied widely, as did the waste gas analysis (i. e., gas leaving the stack), as shown below.

	Top Gas (%)	Waste Gas (%)
CO_2	8.0 to 14.5	0.8 to 16.0
CO	9.1 to 22.0	0.1 to 7.6
O_2	0.10 to 0.65	0.6 to 19.6

In addition, analysis of the particulate was found to vary considerably from one cupola to another. Variation reported was as follows:

	Per Cent
SiO_2	9.3 to 44.0
$FeO + Fe_2O_3$	10.9 to 43.0
CaO	1.9 to 13.4
ZnO	2.9 to 9.2
Al_2O_3	2.0 to 9.6
MnO	0.3 to 7.0
S	0.8 to 6.4
Loss on ignition	0.5 to 39.9

It is obvious from these figures that the gaseous and particulate emission from cupolas varies over wide limits. It is not reasonable, therefore, to expect that dust collecting equipment can be purchased to control emissions from a cupola without first establishing the gaseous and dust emissions for that particular operation.

A quotation from the translation of the book "Kupolofenentstaubung" (Cupola Emission Control) by Engels and Weber states:

> "In the early stages of the development of emission controls, engineers tended to not pay sufficient attention to the different methods of operation of individual cupolas and to generalize on the experience of individual cases. The foundry engineer did not understand that to properly lay out a dust collecting plant required data on the specific cupola operation."

As a means of assisting those foundries in Canada operating cupolas, it is suggested that a team of men be trained in correct measurement techniques and that these men then be sent out to all of the foundries in Canada signifying their willingness to have measurements made on their operation. Such data would be most useful to them, in that they would know more precisely whether or not they would have to install pollution control

equipment to meet a given legislation; if such equipment were required, it could be purchased on the basis of the factual data of their operation. At the same time, we would have a much better picture of the problem of pollution from cupolas in Canada and this could be most helpful in pointing out areas where our research would be of more direct benefit.

(2) There are several articles dealing with the effectiveness of various types of pollution control systems for use on cupolas. The literature on means by which cupola emissions can be reduced by changes in the process is not as plentiful, although a number of articles deal with modifications which increase the output and efficiency of the cupola. Also, several references were found in which general statements such as, "pollutants were less than normal, ..." were mentioned. Only a couple of articles gave actual data on emission reduction and these dealt with the use of natural gas as a supplementary fuel in the cupola, e.g., the stack-dust emission of a 72-inch hot blast cupola was reduced from 67.8 lb per ton to 34.1 lb per ton when 40% of the coke was replaced by natural gas. This same reference indicated potential savings between 50¢ and $1.50 per ton when natural gas was used. Results such as these are most interesting and deserve additional research.

(3) No reference has been found that deals directly with experimental cupola design. Results have been published on data obtained from small cupolas varying from 6 inches to 30 inches in diameter. Battelle have used 15-inch research cupolas for several years and have stated that, "the small cupolas have yielded information which can be applied to larger units, thus convincingly demonstrating their value as research tools." BCIRA, on the other hand, built a 30-inch diameter cupola so that results could be directly applied to industry.

One factor that we must take into account is the effect of size on the particulate and gaseous emissions. The thermal efficiency of a cupola can be expected to decrease as the size decreases due to greater heat losses through the wall. Temperatures in the stack would be lower, and combustion ratios higher. This leads to increased melting losses, and thus higher dust loads in the waste gases. The magnitude of these effects is, however, not known. Another factor is the method of charging. Automatic mechanical charging equipment on large cupolas increases the dust load encountered. On a small experimental cupola, hand charged with necessarily carefully selected scrap and coke, the dust load would be significantly reduced.

The other factor which must be taken into account is space. There is not much sense in installing a 30-inch diameter cupola in a relatively confined space. Such a cupola would produce about 25 tons of metal in 6 hours, the anticipated duration of a test. This would require not only the 25 tons of scrap to be handled, weighed, and charged, or the 5000 lb of coke to be stored and charged, but also the means for disposing

of such a quantity of metal. Consequently, the available space will be very important in dictating the maximum size of cupola which can be operated.

4.7 METALS REDUCTION AND ENERGY

4.7.1 Current Projects

With regard to pollution abatement projects in the Metals Reduction and Energy Centre program, there is at the present time, only a limited amount of work in progress. It is anticipated that more projects related to the serious industrial problem associated with coke-making will be initiated in the near future with increased vigour. Several pyrometallurgical projects are in progress and others in the planning stages.

During recent meetings of the Canadian Carbonization Research Association Technical Committee and also at a subsequent meeting of the Board of Directors, it became apparent from the comments of those members representing the steel industry that this industry is now becoming more conscious of the necessity for studies to improve the health environment of their operating personnel and the surrounding community. One Canadian steel plant plans to increase the soaking time in its ovens to reduce air pollution during the coke discharge. Another plant is interested in the effects of temperature differentials from the top to the bottom of the oven chambers (i.e., heating the oven bottoms hotter than the top may eliminate carbon formation and reduce airborne particulates during oven-push). Also, in this regard such subjects as dry-quenching of coke, preheating of coal and form-coking studies are now attracting more attention. The latter two items are continuing projects in the Metallurgical Fuel Engineering Group activity and it is anticipated that investigations in this area will increase in effort in tempo with industrial requirements. As a result of Dr. Lloyd's report in 1966, the steel industry in Canada and the United States has sponsored research in this area through the American Iron and Steel Institute (AISI).

Kaiser Resources Limited have recently requested assistance in the form of studies to indicate the effect of wind velocity and other aerodynamic effects on the loss of fine coal from unit train transportation. The severity of this problem has been published in an article in the Vancouver Sun, October 2, 1970. A project has been set-up in the Metallurgical Fuel Engineering Group to study ways and means of overcoming the loss of fine coal in transit to tidewater.

The following projects are currently in progress:

A Study to Reduce Loss of Fine Coal during Unit Train Transportation (T. A. Lloyd)

This study is initially confined to a laboratory model to study ways-and-means of reduction of the loss of fine coal from rail car-tops during movement from the mine to tidewater. Up to 1 ton of coal can be lost in this manner during transit. Communities along the route are voicing strong protests against this source of air pollution.

After-burner for Combustion of Off-take Gases from Experimental Coke Ovens (E. W. Montgomery)

A unit was designed by the Combustion Laboratory, Fuels Research Centre, to completely combust the products evolved during the destructive distillation of coal from the Mines Branch 18-inch 800-pound capacity movable-wall oven. This unit was conceived, in the main, to reduce air pollution from pilot plant studies with technical-scale coke ovens. The apparatus may have application in combusting raw gases from coke-oven plants such as on the larry car to permit smokeless charging or in non-recovery coke plants. The first unit proved to be under capacity for the 18-inch oven and will now be tried on the 12-inch oven.

Azeotropic Still for Tar Recovery from Technical-Scale Coke Ovens (E. W. Montgomery)

An azeotropic still is under consideration for producing a dry tar product from the 18-inch and 12-inch coke ovens. Although primarily intended to produce a tar sample for a quality evaluation integrated with the carbonization studies, it will also improve the operating environment. Conceivably this apparatus will be used to evaluate the tar produced from coal carbonized under the different thermal environments now being considered by some plants to reduce carbon formation with resulting air pollution during coke discharge.

Form-Coking Studies (Dr. B. J. P. Whalley and W. Gardiner)

The manufacture of a high carbon product for blast furnace use by means other than the conventional slot-type coke-oven may eventually produce a method with less polluting tendencies.

Pyrometallurgy Section Projects

Most of the current projects in the Pyrometallurgy Section have strong pollution abatement aspects. The facilities and know-how developed in these laboratories in the art of pelletizing is now being used to develop process improvements to minimize dusting or for preparing fumes and dust for waste recirculation. Laboratory experiments have been performed in cooperation with two companies, Union Carbide Canada and Canadian Refractories Limited, to agglomerate pyrometallurgical fumes and dust to facilitate their recirculation. Canadian Refractories has informed us that, based on the results obtained here, they are now performing large scale plant trials. The Union Carbide Canada project is a small part of larger projects; therefore plant trials will not be undertaken until the completion of some smelting experiments in these laboratories.

Experiments are in progress in cooperation with Noranda Research Ltd. on the removal of lead compounds from a baghouse dust product. The technique being investigated is the fuming of these compounds in a rotary kiln from a pelletized charge. The removal of these lead compounds is essential to permit the recirculation of this dust product back into the plant process. The fumed lead product is again trapped in a baghouse dust collector for eventual processing to metallic lead.

The shaft-electric furnace equipment developed in these laboratories during the past seven years appears to have considerable potential as a means of minimizing pollution from smelting operations. Discussions are well advanced with Union Carbide Limited on the organization of an extensive cooperative project to investigate means of minimizing atmospheric pollution from ferroalloy furnaces by improving furnace operating equipment and practices. The utilization of the shaft-electric furnace will be a significant part of this investigation. It is expected that the ores required for this investigation will be delivered within a few months.

4.7.2 Relevant Publications

"Evaluation of Coke Oven Emission", by William M. Smith, 78th General Meeting of American Iron and Steel Institute, May 28, 1970.

"Control of Coke Oven Emissions", by T.E. Dancy, 78th General Meeting of American Iron and Steel Institute, May 27, 1970.

"Curse You Coal Trains", Lew Thomas, The Sun, Vancouver, B.C., October 2, 1970 (press release).

"Urgent Clean Coal Need Stressed", by Bob McMurray, The Province, October 2, 1970 (press release).

"Scientist says Nature Worse Polluter than Man", by Arthur J. Snider, Chicago Daily News, Chicago (press release).

"Use of Coal for Treatment of a Pulping Waste", by F. Daniel Rosenkranz and Peter L. Silveston, Bulletin (CIM), July 1970.

"Discussions with Officials of U.S. Department of Health, Education and Welfare (National Center for Air Pollution Control)", by J.H. Walsh, Metals Reduction and Energy Centre, Report No. 70/38, June 1970.

4.8 FUELS RESEARCH

4.8.1 Chromatographic Analysis of Sulphur Compounds in Petroleum (H. Sawatzky)

One aspect of the chromatographic analyses of sulphur containing components in petroleum is that these analyses could be used for fingerprinting oils or oil fractions and thus identify sources of oil spills. The sulphur compounds in oils vary markedly in both types and quantity. Also the predominant ones are quite stable to oxidation and should be ideal for fingerprinting.

Very little characterization of sulphur compounds in fraction distilling at higher temperatures than kerosene fractions has been done in other laboratories. We have had considerable success in developing gas chromatographic techniques for separating and characterizing sulphur compounds in bitumen fractions distilling in the gas oil range. The sulphur compounds in the gasoline and kerosene fractions have been studied fairly thoroughly in other laboratories but these would be subject to evaporation and thus unreliable for fingerprinting. Our techniques for the gas oils are much less cumbersome than those used in other laboratories for the lighter fractions.

We have had considerable success with thermally stable inorganic gas chromatographic columns and are quite confident that we will be able to perform gas chromatographic studies of sulphur compounds in fractions distilling at higher temperatures than the gas oils. Also we have acquired high pressure liquid chromatographic equipment to deal with fractions too high in molecular weight for gas chromatography.

Other aspects of this work related to air pollution are that a better knowledge of sulphur containing components in bitumen fractions might lead to better refining processes. Also large scale use might be found for some of these undesirable sulphur bearing components and thus make their removal from fuel economically more attractive.

A report on some of this work has been prepared for presentation at the spring ACS meeting.

4.8.2 Desulphurization of Heavy Petroleum Feed Stocks (W.H. Merrill)

As has been stated previously, the objective of the research program of the Petroleum Group is the development of improved techniques for refining the low-grade oil reserves to meet the demands of both the air pollution regulations and the government conservation boards. It is generally felt that practical and economical means to reduce impurities and decrease the quantity of residual products must be developed to permit the orderly use of the whole hydrocarbon energy resource and at the same time reduce atmospheric pollution.

Toward this objective, we have assembled a versatile pilot plant to be used for developing, testing and evaluating, different processes for upgrading crude oils, heavy crude oil fractions and bitumens. This pilot plant, having a barrel-a-day capacity, will also be used for testing the practicability of treatments developed in the bench scale reactors. It is a very versatile plant and can be adapted for many purposes. With slight alterations it can be used as a liquid phase system for thermal cracking and for non-catalytic hydrocracking to reduce the viscosity and the amount of residual material for more efficient use of the total hydrocarbon. It can also be used as a catalytic hydrocracker to restructure and upgrade the material and to reduce the impurities of sulphur and nitrogen for pollution abatement. As a catalytic hydrocracker it can be operated as a once-through process employing either a fixed bed of pelleted catalyst or a slurry of powdered catalyst in a fluidized state. It can also be operated as a recycle process using the powdered catalyst procedure where the products from the reaction are separated in a hot receiver vessel, the heavier fractions being recycled to the reaction for further treatment. By this means, feeds containing appreciable amounts of mineral matter can be treated and the powdered catalyst can be replaced while running. Under these conditions, the residuum content can be reduced to very low percentages, and the pollutants of sulphur and nitrogen all but eliminated. It can be arranged as a strictly vapour-phase system for accomplishing the above on lighter feed stocks. It can also be used as a combined liquid and vapour phase system if required.

Final assembly and testing of the various segments of this high pressure (5000 psi) pilot plant has been proceeding during the period under review and is just now completed. A program is being organized for testing, on this scaled up pilot plant (20:1), several processes that have been developed in our bench scale units. The first to be tested is the thermal non-catalytic hydrocracking process discussed by Dr. Parsons.

During the last few months a contract was undertaken with Canadian Industries Limited to hydrogenate with a minimum of cracking one barrel of their DA-6 bottoms oil. This by-product oil was unmarketable

mainly because of an extremely strong, toxic odour. This odour was almost eliminated by a mild, fixed bed, vapour phase, hydrogenation treatment. It is anticipated that this by-product, which is normally fed to the boilers, can be sold as a commercial solvent. A small treatment plant using this procedure would produce an estimated 10,000 barrels a year of useful solvent after eliminating the pollution due to the very strong toxic odour.

We shall also continue with a program of tests for the treatment of separated Alberta bitumen, which we hope will not only reduce the percentage of residuum material to the level essential for supplying the energy requirements of the over-all tar sand operation, but will supply this residuum in a form which will be easily burned without the serious atmospheric pollution of the present process. The success of this project depends on the development of a suitable cheap, active, disposable catalyst.

4.8.3 Reduction of Air Pollution by Refining of Asphaltic High Sulphurous Resdua by Extraction, Hydrogenation and Synthesis (W. A. O. Herrmann)

Pollution abatement is fine, but if the energy user has to pay more for it then it has to be enforced by government regulations. It appears to be better therefore to find ways to produce energy without intolerable pollution at a price not higher than at present.

The pollution arising from the combustion of fossil fuels stems from four causes: 1) inorganic and particulate matter like ash, 2) heavy metal contained in the fuel or introduced into it as metal-organic compounds like vanadium, nickel and lead, 3) sulphur compounds and 4) the products of the combustion themselves like CO_2, CO and nitrous-oxides.

The formations of carbon monoxide and nitrous-oxides can only be reduced by controlling the excess oxygen and the flame-temperatures. Due to the slow diffusion in solids even at high temperatures, the emission of sulphurous compounds on the combustion of coal or coke can be reduced only by removing them from the off-gases of the combustion as is practised in large central coal firing plants. Contrary to this, gases can be purified in minutes from 25 vol % down to parts per million or less as is practised for the so-called synthesis gases. This operation also requires larger centralized equipment, which is not practicable with vehicles or mobile equipment, which usually burn hydrocarbon fuels ranging in molecular weights from 72 to 294 and spec. gravities of 0.650 to 0.84 kg/lit.

The crude petroleum from which these compounds are usually produced contains, besides the straight-chain and branch-chain paraffines and saturated cyclic compounds, in ever increasing percentages the highly unsaturated high boiling multi-cyclic, multi-layer aromatic components

which contain the larger portion of the sulphur and almost all of the heavy metals contained in the crude petroleum. About 70 to 80% of these heavy metals are deposited in the course of a refining operation onto the catalyst surface and this is the main cause of the deactivation of the latter.

Since the cost of catalyst is about $1.40 per bbl of residuum treated and increases with increasing specific gravity and the concentration of impurities in the feed, any pre-refining step which removes those high molecular components from the feed, will prolong the catalyst life and thus reduce the cost of refining. Simultaneously higher yields due to less hydrocarbon gas and coke formation at lower temperatures and better quality of the products by reduction of the impurities in the products due to the shifting of the equilibrium distribution are achieved.

The simplest way to pre-refine high-boiling, high-molecular weight feed stock is by extraction with very low-boiling hydrocarbons. It is well known, that asphaltenes and high molecular resins due to their higher molecular weight and more cross-linked aromatic structure react much more slowly with hydrogen or hydrogen-rich compounds. The rupture and reconstitution of carbon-carbon bonds, which depends at the conditions of a refining reactor practically only on the temperature, can therefore proceed at high temperature much faster than the hydrogenation. This is the reason why the percentage of resins and especially asphaltenes in the feed determines the yield and the regenerative recycle time of a catalyst due to coke formation on its surface. It is well known that the solubility of these multi-ring aromatic compounds depends on their molecular weight as well as on the dielectric constant of the solvent. This offers the possibility to extract one volume of residuum with about three volumes of a mixture of pentane and hexane, to which butane is added in amounts which regulate the quality of the precipitated asphaltite as well as the raffinate. The raffinate is converted with high yields to the usual refinery products, while the asphaltite is used for roofing and road building. If carbonized, it contains 0.2 to 0.3 wt % of heavy metals and 4 to 5 wt % of sulphur. The Conradson test of the raffinate is reduced relative to the starting material to about 60%, the ash content to 16 to 50%, the heavy metal contents to 30 to 50% and the sulphur content to 5 to 20%. The accompanying table shows the approximate compositions of the feed charge to and the product obtained from this extraction step. This operation can be combined in a very simple way with standard refining. The atmospheric distillation of the residue of the crude petroleum is charged to an extraction column. The top discharge contains the raffinate, the bottom discharge, which forms a well defined separate layer, contains the so-called asphaltite and is practically free of solvent. The top discharge is then charged to another distillation column, in which the solvent is recovered for recirculation. The solvent is obtained as a by-product in the normal refining operation and therefore its cost is negligible. The same holds for the distillation step since it can be combined

with other distillation steps in refining. This process, however, does not actually reduce the sulphur or heavy metals content, it only separates them from the fuels for road vehicles and helps to save some costs.

The hydrogenation, which due to higher hydrogen pressures is able to accelerate the hydrogenation reactions relative to the poly-condensation reactions which occur during refining, can reduce the formation of hydrocarbon gas and coke as well as the sulphur content in the liquid products and the coke quite considerably. While ordinary refining leaves about 10 to 12 wt % of vacuum residuum, which in a fluid coker leaves about 30 wt % coke, or 3 wt % of the crude. The 70 wt % of the crude on treatment in a catalytic cracker leaves 6 wt % coke of the feed onto the catalyst i.e., 4.2 wt % of the crude oil. In total there are 7.2 wt % of coke produced besides (9.4 x 0.7) + (12.5 x 0.3) = 11.1 wt % gas. Compared to 18.3 wt % losses the so-called Combi Hydrogenation yields about 90 wt % of liquid fuels, i.e., 10% losses, which are 1.5 wt % coke and 8.3 wt % hydrocarbon gases.

The gasoline fraction, about 27 wt % of the vacuum bottom feed, contains 0.02 wt % S; the diesel fuel fraction, 41 wt % of the feed, contains 0.45 wt % S and is thus better than specification requirements. The heavy fuel oil fraction, 22 wt % of the feed has a spec. grav. of 0.840, a sulphur content of 0.5 wt % and a Conradson carbon of 0.04 wt %. About 8.3 wt % hydrocarbon gases are formed, consisting to 3/5 of methane and ethane and to 2/5 propane and butane.

I have tried to find catalysts from Canadian raw materials, which would allow to duplicate the results of the commercial Combi-operation in Germany. In autoclave experiments at retention times of 45 minutes at about 456°C and initial hydrogen pressures of 5000 psi or about 350 kg/cm^2, liquid products were obtained without the use of concentrated cobalt molybdate vapour phase catalyst in so to speak one step in some cases in yields of up to 91 wt % of the vacuum bottoms feed. With 2.5 wt % iron oxide tailings as catalyst, its specific gravity can be reduced from 1.043 to 0.823 kg/l and the sulphur content of the diesel fraction to 1.61 wt % and with 1.5 wt % of 10% iron oxide on lignite as catalyst to 0.869 kg/l and 2.34 wt % S. It can be assumed that in a subsequent vapour phase treatment with concentrated cobalt molybdate these pre-cleaned and pre-depolymerized feeds give a very clean product at a cost, which in unit capacities of 100,000 bbl/day or more is comparable to those of conventional refining and about 90 wt % yield of liquid products is obtained, which is never reached by conventional refining methods.

If it is required, however, to produce a fuel, completely free even of traces of sulphur to be used preferably in turbines and diesel engines, without leaving any asphaltic or coke residue at all, then the Fischer Tropsch process should be looked into. If the thermal yield could be increased by making better use of the high heat of reaction by operating at temperatures

of from 280°C to 450°C instead of 240°C and at elevated pressures of about 25 atm instead of atmospheric pressures, thus obtaining this reaction heat in a more valuable form, and if the gasification of the feed material would be performed under pressure in order to use the expansion of one volume $C + O_2$ into two volumes CO or one volume $C + H_2O$ into two volumes $H_2 + CO$ additional energy could be extracted by cooling the hot gases from the pressure gasifier in a gas turbine. The sulphur is extracted from the synthesis gas down to ppm. The catalyst is suspended in an oil slurry and can thus be renewed very easily. From 1 Nm^3 synthesis gas, which has 44.5 vol % CO instead of 33.3 and 55.5 vol % H_2 instead of 66.7, about 160 g of usable fuel products are obtained instead of 125 g as with the atmospheric process. The diesel fraction is reduced to almost 35 wt % and the gasoline fraction increased to 40 wt %. 15 to 20 wt % are obtained as alcohols and waxes besides 10 wt % of unsaturated light hydrocarbons like ethylene, propylene and butylene. The gasoline has a 84 to 88 research octane number, the diesel fuel has a 70 cetane number. The thermal yield of the reaction is about 1680 kcal obtained in products from 2635 kcal charged with the synthesis gas i.e., 63.8%. If the heat losses could be reduced to 7.5%, i.e., 200 kcal per Nm^3 synthesis gas, it could leave 755 kcal/Nm^3 instead of 375 for steam generation. If also from the 3650 kcal/Nm^3 synthesis gas in the coal fuel charged to the gas producers 200 kcal were lost only then in addition to the 2635 kcal/Nm^3 in the synthesis gas, 815 kcal/Nm^3 could be available for steam generation or operation of a gas turbine. If from the total of 1570 kcal/Nm^3 about 38%, i.e., 596 kcal, could be extracted as electrical or mechanical energy, the total over-all thermal efficiency of such a combination of a power plant with a Fischer Tropsch plant would be 62.3%. This still does not compare with the thermal yield of a standard refinery of about 83.3%. But the heat units coming from this refinery correspond to a charge of $3,345 on the raw material, while the same 1575,000 kcal from the Fischer Tropsch-Power plant cost only $1,634 and are in a superior form. Nothing can be said, however, about the other costs of production involved.

Characteristics of Products Obtained from the Petrolether-deasphaltization of Sulphur Containing Vacuum Residuum

Property	Arlan Residuum % of Crude			Romashkine Residuum
	47 wt %	40 wt %	30 wt %	29 wt %
Starting Residuum				
Spec. grav. 2074 kg/l	1.012	1.020	1.050	1.010
Softening point (Ring & Ball) °C	35	40	61	42
Conradson coke wt %	18.0	19.1	26.1	18.8
Fractions up to 500°C vol %	24	18	3	12.5
Asphaltenes wt %	11.7	14.6	17.2	10.5
Resins wt %	29.0	31.2	34.4	18.0
Oils wt %	59.3	54.2	48.4	70.5
Elementing analysis C wt %	83.7	83.3	84.8	84.8
H wt %	10.1	11.3	10.4	11.0
S wt %	4.42	4.50	4.65	3.4
N wt %	0.43	0.52	0.63	0.50
Ash content wt %	0.10	0.13	0.19	0.08
Heavy metals content ppm V	310	370	500	320
N	100	120	150	100
Viscosities at 80°/95°C	153/50.5		does not flow	411/140
Deasphalted Products				
Spec. grav. 2074 kg/l	0.982	0.998	10.15	0.984
Softening point (Ring & Ball) °C	29	35	35	31
Conradson coke wt %	10.5	13.4	15.3	12.6
Sulphur wt %	4.0	4.3	4.6	2.9
Nitrogen wt %	0.37	0.40	0.42	0.40
Heavy metals ppm V	90	170	200	110
Viscosities at 80°/95°C	40.0/17	--	188/65	38.5/14.5
Asphaltite yield	15.16	20.22	24.25	14-15
Ni	50	70	90	55
Asphaltite				
Spec. grav. 2014	1.10	up to 1.11		1.11-1.13
Softening point (Ring & Ball) °C	140	to 170		
Asphaltenes wt %		62 to 68		63-68
Sulphur wt %		5.3 to 6.1		4.2 -4.7
Nitrogen		0.8 to 1.2		0.9 -1.0
Ash content		0.8 to 1.4		0.33-0.35
Metals content ppm V		1100 to 1500		1000 to 1600
Ni		240 to 650		300 to 590

4.8.4 The Coal Mine Refuse Bank at Springhill (T. E. Tibbetts)

Background and Status of Project

The Coal Mine Refuse Bank at Springhill, Nova Scotia is an accumulation of waste products from the mining and preparation of coal. They consist of rock, coal, carbonaceous shale and pyrites as well as mine timbers, brattice cloth, paper and grease and oil containers. Such accumulations are highly susceptible to spontaneous combustion.

Some eleven years ago the presence of fire in the refuse bank located within the western limits of the town of Springhill was noted. This fire was allowed to proceed unabated and unattended and has been and is now a significant local source of air pollution. The smoke and fumes being emitted are obnoxious and considered to be a hazard to the public health. The major air pollutants from burning coal refuse banks include sulphur dioxide (SO_2); hydrogen sulphide (H_2S); carbon monoxide (CO); carbon dioxide (CO_2) and suspended particulate matter. High concentration of these contaminants may have toxic effects on human, animal and plant life. During periods of high humidity—fog and mist--the presence of these emissions reduces the visibility on the local roads to hazardous levels.

The coal mine refuse bank at Springhill is roughly triangular in shape, with a base 1500 feet long and sides of 2400 feet in length. Maximum height is 43 feet and the volume has been estimated at nearly 2 million cubic yards.

Cost of extinguishing the fire in this bank has been estimated at $2 million.

With a view to at least partially absorbing the cost of permanently extinguishing this fire by reclaiming combustible products, the Fuels Research Centre suggested to the town and provincial authorities a core drilling program that would be sufficiently comprehensive to evaluate the quality of the bank material. Such a program was undertaken by the Nova Scotia Department of Mines last July under the supervision of the Fuels Research Centre. The drilling was preceded by an infrared photographic survey in an attempt to isolate areas of high heat levels.

For the drilling program, thirty holes were drilled over the entire area using a Junior Straightline rig with hydraulic head. Drilling procedure was by the hammer and split tube method. Depth varied from 7 to 43 feet. Core recovery was at two-feet intervals and some 400 samples were thus taken.

These samples are presently being evaluated a) by the determination of the proximate analysis at the Solid Fuels Analysis Laboratory

(FRC) and b) by evaluation of the cleaning properties by the float-sink method and by Compound Water Cyclone at the Western Regional Laboratory (MREC). The ash content of the material in the bank varies from 21.8% to 94.4% with an average of 67.0%. The objective of this evaluation is to ascertain the technical and economic potential of producing from this waste bank a saleable coal for use in the area power plant.

We have been requested by the Nova Scotia government to look at the possibilities of conducting similar investigations of five coal mine waste banks in Pictou County. We have indicated our willingness to look at the overall problem in that area and to cooperate at the field supervisory and laboratory stages.

The cost of drilling and core recovery of these banks has been estimated at $35-$50,000.

4.8.5 Arrow Incident - Water Pollution (R.G. Draper)

The water and beach pollution by bunker fuel arising from the "Arrow" incident presented an ideal opportunity to attempt to assess the changes and degradation of bunker fuel due to weathering on open beaches. A series of oil samples taken at stated intervals from set beack locations are to be examined and the various determined physical and chemical properties compared with those of the original cargo sample.

From the results obtained, the laboratory hopes to obtain a better understanding of the effects of weathering and more data on sample source identification. The program is not yet completed.

4.9 COMBUSTION RESEARCH

4.9.1 Committee Activities

(1) International

(a) OECD
- (i) Air Management Research Group
- (ii) Joint Study Group on Air Pollution from Fuel Combustion
- (iii) Planning Group on Long Distance Mass Transport of Air Pollutants.

(b) World Health Organization

(c) World Meteorological Organization

(d) International Flame Research Foundation

(e) ASME, Fuels Division Research Committee

(f) North American Fuel Technology Conference, Tri-sponsored by ASME, I of F and ICFTC.

(2) National

(a) Canadian Council of Resources Ministers Pollution Workshop, October 26-30, 1970.
(b) CSA Air Pollution Control Committee (now reconstituted).
(c) NRC Combustion Sub-Committee.
(d) NRC Associate Committee on Environmental Criteria.
(e) Interdepartmental Committee on Air Pollution.
(f) Mayor Drapeau's Conference on Air Pollution and Noise.
(g) EMR-MOT Joint Planning Committee on Plume Dispersion Research.
(h) Resource Satellite Program - Air Pollution Control Sub-Committee.

4.9.2 Research Projects

- (1) Flame Research Tunnel Furnace (F. D. Friedrich)

Assembly work on this furnace has progressed to the point where exploratory flame experiments are now possible. The Therminol cooling system and flue gas ducting are both completed and fabrication of the continuous sectional probing doors and burner mounting are well underway.

- (2) Characterizing Pollutant Emissions in Relation to Flame Properties (F. D. Friedrich, G. K. Lee, H. Whaley)

This study will be carried out in the tunnel furnace and will form the basis of a thesis toward an M. Sc. degree by Mr. Friedrich at Queen's University. Of particular interest are the interactions governing the formation of pollutants such as NO, CO, O_2, hydrocarbons and soot under different aerodynamic swirl conditions.

- (3) Incineration (F. D. Friedrich, H. Whaley, G. K. Lee)

The review of incinerator practices around the world, which was compiled last year, is presently being revised to include the latest developments in the field. Three research projects, the thermal destruction of liquid DDT, the thermal destruction of solid DDT and the incineration of automobile combustible matter were successfully completed during the year. The latter project was filmed by the department with both a French and English sound-track for circulation by CBC-TV news.

- (4) Fuel Evaluation (E. R. Mitchell, G. K. Lee, F. D. Friedrich)

The combustion properties of crude oil are being evaluated in the pilot scale research boiler at the joint request of Montreal Engineering Co. Ltd. and Ontario Hydro. This evaluation will include a detailed study of the pollutant emission characteristics of both untreated crude oil and crude oil treated with the CCRL additive.

Combustion tests will also be carried on whale oil to determine the best method of thermally destroying stocks, suspected of being contaminated with mercury, without polluting the environment.

- (5) Plume Dispersion Research (H. Whaley, G. K. Lee)

Plume dispersion studies, conducted in collaboration with the Canadian Meteorological Service and the Ontario Department of Energy and Resources Management, were carried out at Lakeview Generation Station, west of Toronto, and in the Sudbury area during May and September respectively. Ontario Hydro participated in the Lakeview study while both Inco and the Department of Indian Affairs and Northern Development contributed substantially to the Sudbury study. These studies have provided original information on the capacity of the atmosphere to absorb pollution under a range of meteorological and topographical conditions found in Canada.

- (6) Pollution Abatement Services (E. R. Mitchell, G. K. Lee, F. D. Friedrich)

(a) Afterburner installations to control combustible content of cupola emissions.
(b) Sampling and evaluation and smelter fumes.
(c) Assessment of crude oil burning characteristics - Ontario Hydro.
(d) Assessment of pitch burning - Iron Ore Co. of Canada.
(e) Isokinetic dust sampling in oil refineries - Esso Ltd.
(f) Particulate matter sampling during soot blowing of oil-fired boilers - CNR.
(g) Boiler heat balance and acceptance testing - DPW.
(h) Incineration of coffee grounds - Goodkey, Weedmark Associates.

4.9.3 Publications

- (1) Lee, G.K., Friedrich, F.D. and Mitchell, E.R., "SO_2 Concentrations in Flue Gas from Two High-Sulphur Canadian Coals", Divisional Report FRC 70/5-CCRL.

Measurements of SO_2 concentrations in flue gases of Four Star and Minto Coal burned in pulverized form are summarized and compared with theoretical.

- (2) Friedrich, F.D., "A Proposal to Study the Effect of Radial Velocity on Turbulent Mixing Processes as Applied to Combustion", Divisional Report FRC 70/11-CCRL.

Turbulent mixing as applied to combustion is described and the index known as swirl number is developed. Experimental procedures and a description of the CCRL flame-research tunnel furnace are also given.

- (3) Lee, G.K. and Jeffrey, R.K., "Inhibition of Sulphuric Acid Corrosion by Water-base Paints", Divisional Report FRC 70/18-CCRL.

A paint formulation (patented by Lee and Mitchell) comprising $Mg(OH_2)$ and $Al(OH_3)$ and suspended in a water carrier is described as well as its effectiveness in neutralizing SO_3 which is emitted to atmosphere from most fuel combustion pollution source.

- (4) Whaley, H. et al., "The Thermal Destruction of DDT in an Oil Carrier", Mines Branch Research Report R 225.

The research and development of liquid DDT incinerator are described.

- (5) Whaley, H. et al., "Air Pollution - Causes and Control", Mines Branch Information Circular IC 211.

The original 1968 publication using 1966 fuel data has been brought up-to-date using 1968 fuel data. The report is an inventory of all fuel combustion air pollution sources in Canada.

- (6) Friedrich, F.D. and Mitchell, E.R., "Air Pollution in Canada from Fuel Combustion", Divisional Report FRC 70/35-CCRL prepared for the OECD committee on Pollution from Fuel Combustion.

The paper presents computations of annual tonnage of pollution from fuel combustion in Canada and projects the amount of CO_2, NO, CO,

particulates, SO_2, SO_3 and total pollutants, all in relation to population, to the year 2000. Automobile pollution was excluded because the OECD committee felt that drastic reductions from the automobile are inevitable.

- (7) Friedrich, F.D. et al., "Characterizing Pollutant Emissions from Flames", Divisional Report FRC 70/55-CCRL prepared for the CGA National Technical Conference, November 1970.

The paper explains that the burning of conventional fuels is Canada's largest source of pollution. Of the three conventional fuels, natural gas is the most pollution free. None-the-less, it shows responsibility for the emission of harmful oxides of nitrogen. The limited knowledge about NO formation in flames and its decay is explained. Also described are research facilities erected in the CCRL and a research program now underway to provide knowledge needed for control of oxides of nitrogen from flames.

- (8) Mitchell, E.R., "Minutes of the First Meeting of the EMR-MOT Joint Planning Committee on Plume Dispersion Research" (no report number).

The minutes of the meeting were the basis of the formal proposal that has been accepted for plume dispersion research. The objective is to determine the pollution dispersion (assimilative) capacity of air sheds or the atmosphere.

- (9) Whaley, H. et al., "The Dispersion of Multiple Plumes from a Large Thermal Electric Generating Station", Divisional Report FRC 70/35-CCRL prepared for the World Energy Conference Plenary Meeting in Bucharest, Romania, 1971.

The paper describes the aerial plume probing methodology developed at the CCRL and the results of a survey of the multiple plumes from the Ontario Hydro, Lakeview power station.

- (10) Fouhse, R.G., "Boiler Performance Tests"
  - (a) Tunney's Pasture - Divisional Report FRC 70/49-CCRL
  - (b) Stoney Mountain Penitentiary, Winnipeg, Manitoba, - Divisional Report FRC 70/56-CCRL
  - (c) National Defence Medical Centre - Divisional Report FRC 70/59-CCRL.

These reports describe heat balance tests in Department of Public Works heating plants. Summarized are operating conditions which provide maximum thermal efficiency with minimum pollution.

- (11) Mitchell, E. R., "Alternate Platform for Air Pollution Monitoring", Informal report of the Resources Satellite Program, Air Pollution Control Sub-Committee.

- - - - -

APPENDIX

DEPARTMENT OF ENERGY, MINES AND RESOURCES
INLAND WATERS BRANCH
WATER QUALITY DIVISION

MINE WASTEWATER TREATMENT RESEARCH PROGRAM

A PROGRESS REPORT

Prepared for the Second Seminar
MINES BRANCH PROGRAM ON ENVIRONMENTAL IMPROVEMENT
November 17, 1970.

by: J.W. Schmidt
Water Pollution Research Subdivision

MINE WASTEWATER TREATMENT RESEARCH PROGRAM

A PROGRESS REPORT

WATER QUALITY DIVISION - INLAND WATERS BRANCH

At the federal level the Inland Waters Branch provides services in physical sciences and engineering needed for the optimum management of Canada's water resources. Scientific or engineering data, research results, engineering studies, appraisals or advice are provided by the Branch. Although primary emphasis in this article is on the Water Quality Division which has a major research program underway in the mining industry, a brief outline of the Branch organization and background of the Division's involvement in this area is provided.

To carry out the functions of the Branch, it is organized into the following groups:

Water Survey of Canada - Responsible for the measurement of stream flow, water levels and sediment transport and other related functions throughout Canada.

Lakes Division - Conducts comprehensive limnological studies on lakes to provide requisite information for optimum resources management with the initial studies being oriented towards the Great Lakes and the problem of eutrophication.

Hydrologic Sciences Division - Undertakes research into the physical processes governing the behaviour of water in the hydrologic cycle to improve methods of water management.

Programs in glaciology, groundwater research and fundamental studies on water are presently underway. Pertinent studies include those on the use of deep wells as a means of industrial wastewater disposal and fundamental studies on copper to determine the form in solution which may be toxic to aquatic organisms.

Canada Centre for Inland Waters - This is a major inter-disciplinary research centre located at Burlington, Ontario, for studies in water research. This centre is currently under construction with one major building recently being opened.

Water Quality Division - The broad objective of the Water Quality Division is to collect, interpret and disseminate data on the quality of inland waters in Canada and to conduct applied research in water chemistry and in water and wastewater treatment to permit the optimum utilization of Canada's freshwater resources.

WATER QUALITY DIVISION

The functions of the Division are carried out by the following three major Subdivisions.

1. Resources and Surveys Subdivision

The function of the Subdivision is to establish and maintain water quality monitoring and surveillance networks in Canada in support of various water resource studies and programs. One of the more important objectives is to provide base-line data on water quality in any particular area.

2. Water Chemistry Subdivision

The function of the Subdivision is to provide comprehensive laboratory services in support of departmental water resource programs and other related studies. At the present time laboratories are operating in Moncton, Calgary and Ottawa with a group from Ottawa located in Burlington at the Canada Centre for Inland Waters.

One section of the Subdivision is actively engaged in the research and development of new methods of analysis. The automation of methods and the continuous recording of data are primary objectives.

Considerable work has been carried out on the evaluation of specific ion electrodes and a suitable method for the analysis of cyanide in mining effluents. Recently published was a method for the detection of low concentrations of mercury in water.

3. Water Pollution Research Subdivision

The function of the Subdivision is to conduct applied research on the treatment of water and wastewater to provide practical methods for water pollution abatement.

Specifically, it is intended to assist industry in the development of effective pollution abatement methods;

- by examining present processes and techniques for pollution abatement and assessing their applicability to Canadian industry and conditions.
- by furthering the dissemination of information to industry by the provision of a central information centre and by fostering conferences and seminars.
- by otherwise supporting industrial and university pollution abatement research by the award of contracts.
- by participating in and promoting committees for the purpose of co-ordination of the research effort.

The Subdivision has concerned itself initially with applied research on the treatment of wastewater from the mining and pulp and paper industries. However, the program will be expanded to include the petroleum, petrochemical, chemical, food and textile industries. Envisaged, also, are intensive studies on the treatment and reuse of municipal wastewaters.

The Subdivision's laboratory program is currently being carried out in Ottawa. However, in mid-1971 it is anticipated that the group will relocate in Burlington at the new Canada Centre for Inland Waters. At this Centre the group will be housed in the Water Quality Pilot Plant, a building with about 25,000 square feet of pilot plant and laboratory working space.

Common user laboratories will be available for the private sector in the Water Quality Pilot Plant building. Industries are encouraged to participate in co-operative studies and develop prototype systems for continuing on-line studies at operating industrial sites.

With respect to the management of the Water Quality Pilot Plant an advisory committee has been formed consisting of technical people representing the provinces, universities, industry, consulting engineers and other federal departments. Advice is being sought initially on such aspects as equipping the pilot plant, research priorities, specific research proposals and allocation of space and facilities.

To briefly summarize, it is the objective of the Division to provide as much continuity as possible in the survey and analyses of water quality (including the development of suitable analytical methods) and the research, application, and development of improved pollution control measures. Where Division surveys show pollution to be a problem, studies are carried out on the source of pollution, ie. the discharge of wastes from the industrial operation. With respect to the mining industry, then, the Division is concerned with all aspects of the disposal of mine tailings and wastewaters (mine and mill) as well as the measurement of downstream water quality.

It is recognized that many industrial waste disposal problems may (and should) be solved within the industrial process, but, our studies are confined to the process wastes themselves, seeking only that production and process information which will provide an understanding of the wastes at hand and the variations that can be expected in quantity and quality.

It is in the area of source control where a major role is foreseen by others, particularly the Mines Branch. The elimination of process wastes or the development of closed systems provides an ideal answer to the problem of pollution.

The following paragraphs trace the early history of the mining program and outline the specific program in which the Division is now engaged.

MINE WASTEWATER RESEARCH PROGRAM

In 1960, the Fisheries Research Board, in the course of studies on migrating salmon in the Miramichi River in New Brunswick, first observed the adverse effects of base metal mining. Wastewaters were derived from a mine located near Newcastle and their toxicity was attributed to minute (parts per billion) concentrations of dissolved copper and zinc, to each of which the young Atlantic Salmon is particularly sensitive..

Several years later another mine began operations near Bathurst and the stream receiving the tailings pond effluent was also

toxic to fish, apparently because of the concentrations of copper and zinc present.

Prior to 1966 the Department (Industrial Waters Section, Mineral Processing Division, Mines Branch) provided advice on this problem to both the New Brunswick Water Authority and to the Department of Fisheries and cooperated with the latter Department by analyzing samples collected by them. In 1967 an expanded program was initiated by the Inland Waters Branch involving personnel from the Hydrologic Sciences Division, the Water Survey of Canada and the Water Quality Division.

These studies were designed to provide basic information on the transport of materials from the mining operations into adjacent streams. In collaboration with the mines, daily effluent sampling programs were initiated in conjunction with the installation of automatic equipment tc measure pH and conductivity. Later in 1967 a trailer laboratory was established on the Little River near Bathurst to continue the monitoring studies throughout the winter.

The results of this monitoring program were reported at the First Annual Meeting of the Canadian Mineral Processors in Ottawa in 1969.

Subsequent to these field studies, laboratory research by the Water Chemistry Subdivision was initiated to identify the materials lost from mining operations. Both organic and inorganic materials were to be studied by appropriate techniques. In this regard studies on the identification of xanthates in tailings pond overflows and their role in the transport of materials were initiated as well as a study on the characterization and behaviour of colloidal materials in mine wastewaters.

In late 1969, however, because of a change in Division project priorities these studies were suspended.

MINE WASTEWATER TREATMENT RESEARCH PROGRAM
(Water Pollution Research Subdivision)

PROGRAM: Abatement of Pollution by Tailings Pond Overflows

PROJECT: Field Investigation of an Acidic Stream Receiving a Tailings Pond Overflow.

At the mine near Bathurst, tailings from the mill are discharged to a tailings pond system covering approximately 300 acres. Suspended solids and heavy metals are fairly effectively removed by this system and the pH of the decant, although quite variable, is generally acceptable for discharge to a watercourse. In this stream, however, the pH progressively decreases reaching a minimum of about 2.5 and at one location downstream the pH generally remains in the range 2.5 to 4.0 throughout the year.

This problem had been previously identified but not resolved and in 1968, with the co-operation of the mine, an on-site investigation was carried out by the Division. Although the exact mechanism of acid production in the stream was not completely understood it appeared to be caused by (a) a continuing chemical oxidation of thiosalts to sulphate with the accompanying production of acid, and (b) predomonantly, the bacteriological oxidation of thiosalts to sulphate with the accompanying production of acid.

Thiosalts, of course, would be expected in the tailings because of the alkaline oxidation of pyrite materials in the mill and the use of SO_2 in the flotation circuit. Analysis on samples subsequently collected throughout the mill confirmed this.

Although only the problem of pH depression was examined in detail, the data collected indicated the presence of other potential pollutants such as the heavy metals and excessive concentrations of residual organic materials, probably flotation reagents.

These findings were reported at the First Annual Meeting of the Canadian Mineral Processor's Association in Ottawa, January 1969.

PROJECT: Treatment of Tailings Pond Overflows.

On the basis of the above findings and in consultation with the company a laboratory program was initiated to devise an economical, effective treatment process for this wastewater. The specific process engisaged would involve the oxidation of these thiosalts in solution to

the stable sulphate, neutralization of this effluent and the discharge of stabilized water to the receiving stream. After an extensive review of the literature and consideration of a number of alternatives such as chemical oxidation, it was decided that the most promising area for research was biological treatment of this type of wastewater with subsequent neutralization and clarification.

Laboratory studies on the biological treatment of thiosalts containing wastewaters were initiated and are continuing at the present time using continuous flow, completely mixed, aerated reactors without recycle. The overall objective of the laboratory studies is to develop engineering design criteria for such systems.

Although, as mentioned, other problems with tailings pond overflows have been identified, no research is being conducted in these areas at this time, but future research is anticipated.

PROJECT: Pilot Scale Treatment Studies

For the treatment of thiosalts containing wastewaters, in addition to the laboratory studies, and in conjunction with the mining company, a pilot plant project was initiated. A pilot scale treatment system was constructed by the mine and consisted of two biological oxidation ponds which were operated independently, one being seeded with bacteria, the other serving as a control. The effluent from the tailings pond system was fed to the ponds at a rate of 15 gpm. Operations were terminated in late fall because of the cold weather and the failure of a portion of the dyke between the two ponds. Results of this work were inconclusive in fully defining the parameters necessary for a full scale treatment system.

No further work on this type of process is anticipated because the mining company is having constructed a full scale facility which is almost complete at the present time. This facility will incorporate a treatment system similar to that outlined, as well as provision for the recycle of the effluent to the mill.

This approach, water reuse, is probably the most desirable one for the complete elimination of problems with mine wastewaters.

PROGRAM: Provision of Technical Assistance and Advice

Another problem which occurs at numerous mines is that of acid mine drainage, a problem common to many areas where pyritic materials are found. These waters are characterized by an acidic pH and excessive concentrations of heavy metals such as copper, zinc and lead. This drainage is derived from underground operations or from areas where water and oxygen can react with pyritic materials.

The Subdivision, although not carrying out specific research in this area - (a proposal is currently under consideration) has been actively advising and assisting one of the larger Canadian mining companies in the solution of this type of problem which exists at several of its mines. In general, specific assistance has taken the form of the analysis of samples in order to identify the materials responsible for the problem, and the interpretation of the analysis in relation to its point of collection and its chemical and biological characteristics. Suggestions have been forwarded to the companies involved as to measures which they may wish to consider for corrective action.

In this regard a number of mines have been visited and advice tendered where requested. Specific areas visited were northern New Brunswick, northwestern Quebec, the Sudbury area of Ontario and central British Columbia.

In addition, technical advice on various aspects of pollution abatement technology has been provided on request to various other federal and provincial departments concerned with pollution from the mining industry.

The program of provision of technical advice and assistance is one of high priority and expansion in terms of both volume and effectiveness is being actively considered.

MINE WASTEWATER TREATMENT RESEARCH PROGRAM

PUBLICATIONS (P) AND REPORTS (R)

1. 1969 (P)
"Abatement of Pollution from Mine Wastewaters"
J.W. Schmidt and K. Conn
Proc. Can. Min. Proc. 1969 (IWB Reprint Series NO. 52)

2. 1969 (R)
"Oxidation of Iron Sulphide Minerals"
F. Standeven (Report prepared for the Department of Coordination and Placement, University of Waterloo)

3. 1969 (R)
"Study of Chemical Treatment of Partial Oxidized Sulphur Compounds"
F. Standeven (Report prepared for the Department of Coordination and Placement, University of Waterloo)

4. 1970 (R) (Confidential)
Mine Wastewater Treatment Research - Technical Investigation
"Brunswick Mining and Smelting Corporation Limited, Bathurst, New Brunswick"
J.W. Schmidt and K. Conn

5. 1970 (R)
Mine Wastewater Treatment Research - Interim Report No. 2
"Biological and Chemical Laboratory Scale Studies of the Treatment of Mill Wastewaters"
J.W. Schmidt

6. 1970 (R)
Mine Wastewater Treatment Research - Interim Report No. 3
"Pilot Scale Studies for the Treatment of Mill Wastewaters"
J.W. Schmidt

7. 1970 (P)
"Abatement of Water Pollution in the Base Metal Mining Industry
J.W. Schmidt and K. Conn
Submitted for publication to the Canadian Mining Journal, October.

8. 1970 (R)
"Methods for the Determination of Some Sulphur Anions in Wastewater - A Brief Review"
F. Standeven (Report prepared for the Department of Coordination and Placement, University of Waterloo)

9. 1968 (P)
Pollution Problems Associated with Base Metal Mines"
A.E.P. Watson
Proc. Fifth Annual Meeting of the Canadian Gold Metallurgists, 34, 1968.

10. 1969 (P)
"Pollution Problems Associated with Base Metal MInes"
A.E.P. Watson
Proc. First Annual Meeting of the Canadian Mineral Processor's, 30, 1969.

11. 1970 (P)
"An Automated Method for Determining Mercury in Water"
P.D. Goulden and B.K. Afghan
Inland Waters Branch Technical Bulletin No. 27, 1970

12. 1970 (P)
"The Determination of "Total Mercury" Levels in Water"
P.D. Goulden and B.K. Afghan
Presented at the "Technicon International Congress on Automated Analysis", New York City, N.Y. Nov. 1970 (Paper No. 76).